Spaceflight

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Above the Mare Nectaris.
Painting by David A. Hardy, F.R.A.S.

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Editorial

The launching of Sputnik III, at almost the moment when the present issue of *Spaceflight* was going to press, represents another major achievement by the scientists of Soviet Russia. Details so far available show that the new satellite is considerably heavier than the last, with an initial weight of well over a ton, and that it is differently shaped; like its predecessors, it naturally carries radio equipment, which at the time of writing (May 18, 1958) is still in operation. Evidently it carries no animal passenger.

Full details about Sputnik III will be published in the next issue of *Spaceflight*, when some preliminary results may also be available. Meanwhile, everyone will wish to send fresh congratulations to the Russians upon their magnificent work.

It is most regrettable that the British press, at least, took so little notice of the launching. So far as nearly all national papers were concerned, various political crises ousted the satellite from their headlines, and on the following day some papers—*The Times*, for instance—failed to mention Sputnik III at all. It may be felt, and with justification, that the editors concerned should be much more far-sighted than this; it is no longer possible to live in the past, and the successful launching of Sputnik III will be remembered when all the childish political squabbles of the time have been mercifully forgotten. Meanwhile, it seems necessary only to say that the new Russian achievement brings the true "Space Age" yet nearer.

May 19, 1958. PATRICK MOORE

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The Photographic Observation of Artificial Satellites

By M. J. HENDRIE, F.R.A.S.

Prior to the launching of Sputnik I it had been assumed that the first satellites would be faint objects barely visible to the naked eye even in the most favourable circumstances. The second Russian satellite and the last-stage rocket of the first have both been visible as bright objects, at times brighter than any of the stars. Because they have been so bright it has been possible to photograph them with small cameras in spite of their rapid motion across the sky. The fainter satellites to be launched this year from the United States will still require the large super-Schmidt type of tracking telescope with its special mounting and control unit (well beyond the reach of the amateur) for photographic observation and the "Moonwatch" stations with their dozen or so observers to allow them to be followed visually. It is however reasonable to suppose that during the next few years there will usually be one or more satellites circling the Earth comparable in brightness with the two we have already seen.

Optical observations may be made either visually or photographically. Only photographic observation using simple methods and equipment will be considered further here. It is assumed that those observers intending to undertake photographic work will already have some understanding of the practical aspects of photography and the emphasis is on those phases of the subject that are likely to be new to those unfamiliar with the general requirements of astronomical photography. The accent is on simplicity so that useful results may be obtained as soon as possible: this does not mean that there is no scope for improvement or more ambitious projects, but it is advisable to observe first of all and improve later when the various difficulties have been assessed by the observer himself.

Optical Requirements

For practical purposes artificial satellites, of the sizes likely to be visible during the next few years, may be considered as stars; that is, as moving points of light. Since the size of the image of a star depends on the focal-ratio of a camera lens*[1] and a lens of 4 in. aperture and 12 in. focal-length will collect four times as much light as a lens of 2 in. aperture and 6 in. focal-length, four times as much light will be concentrated in the image of the first as in the second. Both these lenses are f/3 but the larger one has a scale (the linear distance in the focal plane corresponding to an angular distance in the sky) of twice that of the smaller because scale is proportional to focal-length. In a given time the moving star image will make a trail twice as long in the larger camera as in the smaller and the light will be spread out over twice the area.

The larger lens will therefore photograph moving point objects about twice as faint as the smaller. Small miniature cameras can be seen to be at a considerable disadvantage despite their fast lenses. They will however photograph the satellites near their brightest quite satisfactorily.[2]

For the most useful results lenses of large linear aperture and small focal-ratio are required. These optical requirements are very similar to those of meteor photography with one important difference; that the object may be brought to the centre of the field of view. Of the lenses that have proved themselves in meteor work two may be mentioned both of which are suitable

MICHAEL J. HENDRIE

Born 1931. Joined B.I.S. 1950. Joined B.A.A. 1951. Member of Comet and Meteor Sections. Principal interest in astronomy, photography of comets and meteors. Special interest in physical aspect of comets. Built own observatory with 6 in. reflector on equatorial with cameras, specially built for comet photography. Elected F.R.A.S. 1957. Amateur. Employed by a major oil company.

* This image is that formed by the lens; in a perfect optical system its linear diameter is given by

$$\frac{F}{D} \times \frac{4{\cdot}56}{206{,}265} \text{ inches,}$$

where F and D are the focal-length and aperture respectively in inches. The actual image on the photograph is rather larger than this due to turbidity and the unsteadiness of the atmosphere.

for satellite photography. The Kodak Aero-Ektar f/2·5 lens is made in focal-lengths of 7 and 12 in. It will cover a field 50° in diameter with sufficiently good definition. The Ross Xpres Wide-Angle f/4 lens is available with a focal-length of 5 in. and will cover a field of 75°.[3] The Aero-Ektars are becoming rather scarce but the Ross Xpres Wide-Angle can still be bought for upwards of £5. Good results may be obtained with lenses as slow as f/6, but faster lenses are really desirable, as we have seen.

Fortunately a large field of good definition is not essential for satellite photography if the camera is equipped with a sighting device and a universal type of mounting. This means that one may use the much more easily obtainable and less expensive portrait lenses. Portrait lenses have a much smaller field of good definition than the anastigmats but it can easily be arranged to bring the part of the trail to be measured to the centre of the field. Those of 2 in. aperture or larger should be chosen with focal-ratios of between f/2·5 and f/4; it is advisable to look out for those by reliable makers such as Dallmeyer and Voigtländer.

Focusing and Squaring-on

The approximate focal-length of a lens can be found by focusing the image of the Sun, Moon or a distant scene on to a screen and measuring the distance from the lens to the screen. This is sufficiently accurate to allow the size of the camera to be decided. A simple wooden box camera is all that is required but it must be made strongly and well put together with glue and screws. Fig. 1 shows the method of construction of the camera shown in Figs. 4 and 5. Before the camera is finally assembled the position of the focal plane should be checked by placing an exposed plate or a ground-glass screen against the levelling screws and bringing a distant object into focus. Sufficient length must be left to enable final adjustments to be made after assembly. For the levelling screws, against which the emulsion of the plate rests when the camera is loaded and the dark slide withdrawn from the plate-holder, ordinary wood type screws about ¾-in. in length are used.[4] Holes should be drilled in the back panel of the camera to take them so that they are a tight fit but do not have any tendency to split the wood. The use of 9-ply for the end panel and the two bulkheads supporting the lens is recommended.

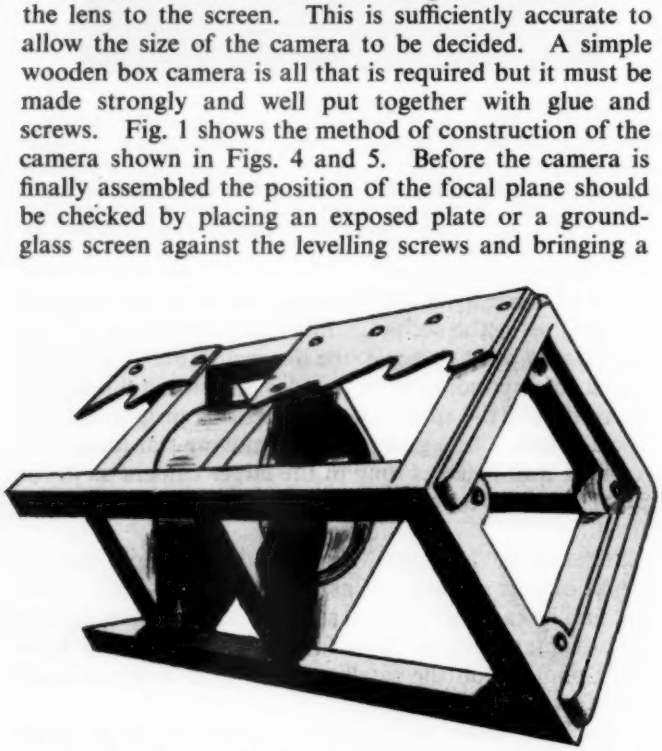

FIG. 1. A cut-away diagram of a simple wooden box-camera for a 3-in. portrait lens. Notice the double bulkhead to prevent the lens from sagging, the levelling screws fitted so that they actually come into contact with the surface of the plate itself when the dark-slide is withdrawn from the plate holder, and the guides for the plate holder. The crossbar and wedges to hold the plate against the levelling screws are not shown but can be seen in Fig. 4

When obtaining the rough focus before making any exposures it is helpful to use the Sun or the Moon to enable the plate or ground-glass screen to be set roughly perpendicular to the optical axis of the lens. A portrait lens will not give images of the same shape and size all over the plate but it should give similar images at given distances from the optical axis. By adjusting the levelling screws until the images do appear the same size and shape near each corner of the plate considerable time will be saved when it comes to the final squaring-on.

Final adjustments to the focus must be made using the stars themselves. If the lens has a smoothly working rack and pinion or screw-thread focusing device this can be used for the initial focusing. Final adjustment is best made with the levelling screws in the back of the camera, as it will be necessary to clamp the lens in position when it is focused to prevent accidental movement and this may put the lens out of adjustment again if left until last of all. A series of exposures is made on the night sky and after each the camera is tilted slightly (to avoid overlapping of the star trails) and the levelling screws are turned so as to alter the focus by a small known amount. Fig. 2 shows the appearance of such a trial plate. There would, of course, be more than one set of trails on the plate but the set nearest to the centre should be used. If the trails are getting sharper or broader another exposure must be made beyond the limits of the first set. If, however, the trails become sharper and then broader again as in the figure, the best focus lies within the range of positions tried.[5] The focus should then be set to cover the positions where the focus was sharpest and another trial plate exposed in the same way except that the focus should only be altered by a smaller amount this time. The broken trail in the figure is made by cutting off the light from the lens for about half a minute and provides positive information that this particular trial was the last made. Until again altered the lens is focused for this position. It is advisable to maintain a record of all adjustments made when focusing and squaring-on a camera as it is very easy to make a mistake which will necessitate doing some of the tests again. For the best results the emulsion on the plate should be within one-tenth of a millimetre of the focal surface of the lens.[6]

To achieve this accuracy requires considerable perseverance but the importance of really accurate focusing cannot be over-estimated. A poorly focused camera will not photograph nearly such faint objects as it

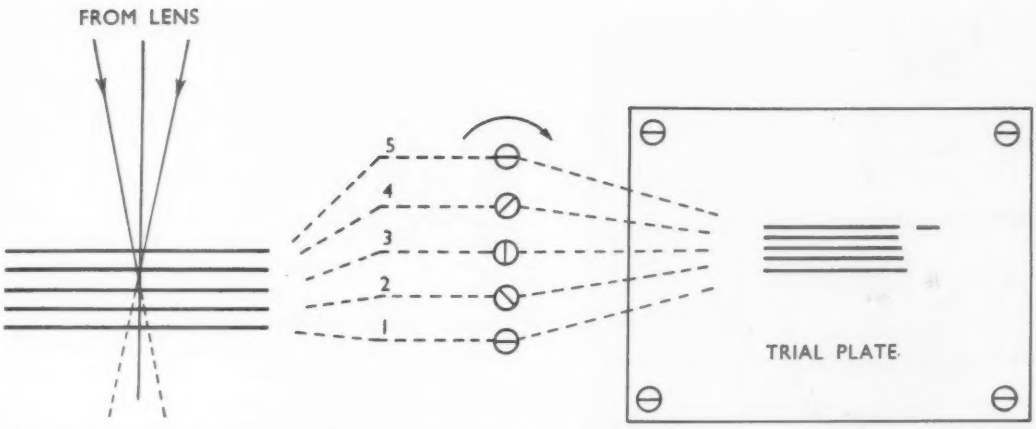

FIG. 2. Five separate exposures have been made on the trial plate (right) by turning all the screws $\frac{1}{8}$th of a revolution (clockwise) after each exposure. The narrowest trail is No. 4 and the broken trail identifies the fifth. On the left are the corresponding positions of the plate relative to the converging cone of light from the lens

should; and even if they are recorded, their images will not be sharp enough for really accurate measurement. There will of course be far fewer stars on such a photograph, too, for the same reason, so that even with a bright satellite the observation may be of little value.

Fig 3 shows how the plate can be turned about an axis passing through the centre of the plate without altering the focus. If the optical axis passes through or very near to the plate centre it will be possible to get the images similar in all four corners and still preserve the focus at the centre. This is achieved by making trial sets of exposures on stars as for the focusing, but this time the levelling screws are turned equal amounts in opposite directions on the opposite sides of an axis about which the plate is to be rotated. Only a small movement should be made each time as the correction should not be large if care has been taken with the earlier stages; about one-eighth of a turn for $\frac{3}{4}$-in. wood screws of medium gauge is about the right amount. When the trails of the stars appear similar in all the corners of the plate the camera is ready for use, except that a further slight adjustment to the focus may now be necessary; this should be very small and easily corrected by exposing another trial plate but moving the screws only a very slight amount each time. All celestial objects are at infinity for practical purposes and once focused the camera should remain in adjustment almost indefinitely if handled with care; excessive dampness should, however, be avoided for wooden cameras. It is advisable to keep the camera at outdoor temperature or at least to take it out an hour or so before observing so that it may settle down to an even temperature. As exposures will be short, dewing will not be a problem but the extension of the camera body in front of the lens will act as a lens hood to keep out stray light during exposures.

Plates and Developing

For astronomical work plates are generally preferred to film, as it is difficult to keep film really flat as it must be, if sharp images are to be obtained. Also, as it is necessary to examine each photograph within a few minutes of taking it, the use of roll-film is rather wasteful. Cut-film has most of the disadvantages of roll-film and

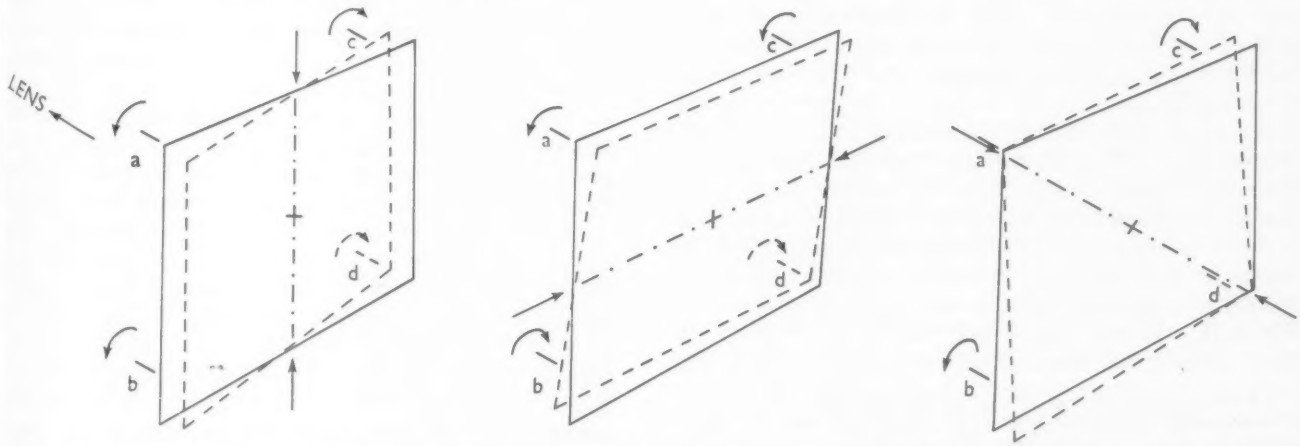

FIG. 3. The three diagrams show how the plate may be turned about one of four axes without altering the focus at the centre

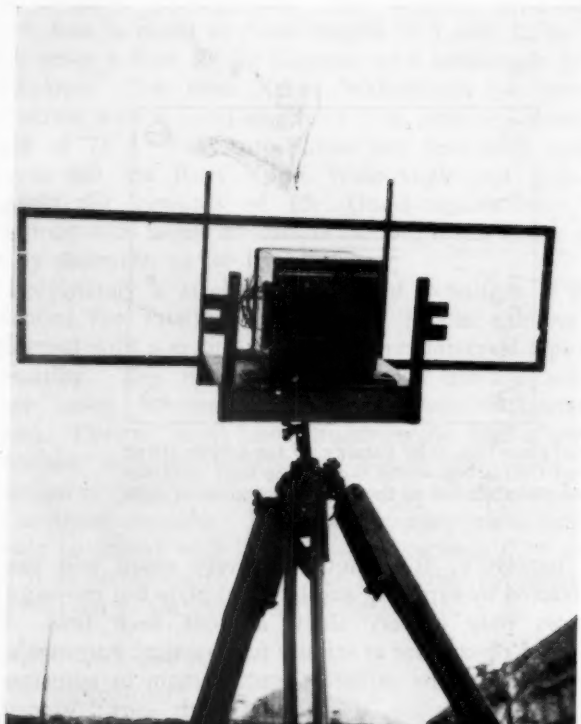

FIG. 4. $3\frac{3}{8}$-in. aperture portrait lens camera on tripod. The rear sights and wooden frame to support the string reticule (which cannot be seen in the photograph) which enables the satellite to be guided across the centre of the plate can be seen. Notice the crossbar and wedges which keep the plate holder firmly in position, and the large wing-nuts for locking the motions of the tripod head

no real advantage over the plate. In general, however, the remarks that follow, apply also to film, although films will not be considered separately. Observers using ordinary cameras will of course have to use film, and they will already be familiar with its own peculiarities.

For portrait lenses the small field of good definition will not justify the use of plates larger than quarter-plate size ($3\frac{1}{4} \times 4\frac{1}{4}$ in.). To make the best use of the wide field of the Aero-Ektar's and Ross Xpres's will require the use of plates at least half-plate size ($4\frac{1}{4} \times 6\frac{1}{2}$ in.) or better still whole-plate ($6\frac{1}{2} \times 8\frac{1}{2}$ in.). A whole-plate will cover about 50° by 70° of sky using a 7-in. focal-length Aero-Ektar. Although the total exposure time may be a minute or two, the light from the satellite falls on any one part of the plate for a very short time and a fast plate is therefore required. Ilford HPS has been found to be the most suitable plate available in this country for meteor photography and it is also very suitable for satellite work. In any case a fast panchromatic plate (or film) should be used where possible.* Films and plates should be developed to give maximum speed and contrast. Kodak 19b X-Ray Developer used at full-strength (5 min. at 68° F.) gives very good results with HPS plates and is used for comet and meteor photography where high speed and contrast are required, with a variety of different types of plates and film. Care should be taken not to over-develop a plate taken in strong twilight; even a few seconds' exposure will fog a plate even when it seems fairly dark to the eye. No general guide can be given as conditions are always varying, but as the satellite will often be visible in twilight experiments should be made to enable the observer to gain the necessary experience.

* Portrait lenses are only corrected for blue light. If difficulty is experienced in obtaining a sharp focus, blue sensitive plates should be tried. Usually this change will be unnecessary for trailed images.

Mounting the Camera

A fixed equatorial mounting is of little use to the satellite photographer unless he can calculate the position of the satellite in the sky and set his camera accordingly. This takes time and when available information is unreliable, as it may be in the earlier or later stages of a satellite's life, it may be impossible. By far the best method is to have a type of universal mounting, preferably on a very steady tripod so that it can be moved to the most suitable vantage points. This will allow the camera to be pointed to any part of the sky at a moment's notice. Such a tripod may be made or obtained from Government surplus stores or optical shops. The ex-Government ones are usually the best and some are at present on sale at far less than the cost of the materials alone. The flimsy wooden or metal folding telescope stands should be avoided. Solidity is most important and it would be better to make up a stand from 3 × 2 in. wood than buy one of these light-weight tripods. The one shown in Fig. 4 has a rotatable head, adjustable elevation to the stem supporting the ball, and a smooth working ball and socket head of adequate size. All movements have locking wing-nuts, and it folds down to about $2\frac{1}{2}$ ft. long when closed. Extended it places the camera at convenient eye-level. It supports the $3\frac{3}{8}$-in. aperture camera weighing 10 lb. in any attitude without vibration and the movements can be locked or unlocked in a second. Similar tripods are available in London at about £3.

The sighting arrangement was made of thin wood strips and white string. This was originally only a temporary arrangement but has proved to be quite adequate. The inner string rectangle (Figs. 4 and 5) nearest the camera marks off the adjacent half of the plate. The position of the strings can easily be decided by pointing the camera towards a distant scene with a screen or exposed plate in the back of the camera. The objects on the edges of the screen can then be seen through the rear sights and, by holding a strip of wood against the outer frame of the sights, this strip can be brought into position until the same objects just lie within the field of view. A mark is made on the frame, and when all four sides of the plate have been similarly examined and their corresponding positions on the frame marked, the string or white wire may be tied in place

on the frame. By putting one's eye to the rear sight one can guide the satellite in between the "horizontal" strings and centrally across the plate. When it disappears it is in the centre of the plate. By making the sights symmetrical about the camera they can be used equally well when the satellite is moving from left to right or right to left across the sky, which depends on whether it passes to the north or south of the observer.

Observation Conditions

Even when accurate predictions are available for a satellite it is impossible to know exactly what its appearance in the sky will be like. The altitude above the horizon may be calculated for a point on its path and the apparent rate of motion also, but the brightness depends not only on its distance from the observer, but also on phase (angle at the satellite between the observer and the Sun), orientation of the satellite (unless it is a sphere of uniform reflecting power) and on the absorption of the atmosphere which increases rapidly as the apparent altitude decreases. For an object 10° above the horizon atmospheric absorption amounts to about one magnitude,* but this does not include that due to haze, fog or cloud. In addition to these factors which are beyond the control of the observer there is also the effect of the fogging of the plate due to twilight or moonlight, which if allowed to become excessive, can completely obscure the trail left by the brightest object. As satellite observations will often have to be made when there is strong sky-light present, exposure times should be kept as short as possible when lenses of small focal-ratio are being used. In fact there is no necessity to prolong exposures as the trail of the satellite need only cover part of the plate and, as the stars are also moving across the sky due to the Earth's rotation, longer exposures will not record any fainter stars when a stationary camera is being used. The maximum desirable exposure can only be learnt by experience but it is better to have only a short trail with very little plate-fog than a long one where the stars have been lost in the background fog. Exposure will seldom require to exceed a minute and 10 to 15 sec. is usually sufficient except with the smallest lenses where the effect of the movement of the stars in a given time is much less.

Methods of Observation

Three methods are suggested as covering the requirements of the observations required and making the most economical use of each type of camera and plate-size combination.

(*a*) The satellite is allowed to move on to the plate and when in the centre of the plate the exposure is terminated, this time of ending the exposure being noted. For this method an exposure of 20 sec. would be sufficient and could be reduced to half this. The plate can

* A sixth magnitude star is 100 times fainter than one of first magnitude. A difference of one magnitude is equal to $\sqrt[5]{100}$ = 2·5119 times.

FIG. 5. $3\frac{3}{8}$-in. aperture portrait lens camera showing ball and socket joint and supporting stem which is adjustable for elevation, the whole of which is rotatable about a vertical axis

then be changed and another exposure made near the next peak of brightness if the satellite is varying; if it is not, choose a point where it is amongst bright stars. Fig. 7 was taken in this way.

(*b*) Where there is too little time to change a plate between exposures, two photographs may be taken on one plate. The same procedure as for (*a*) is used except that for the second exposure the camera is tilted relative to the satellite's path. The second exposure is terminated in the same way as before but continued again after about 30 seconds for another half-minute or so. The result is something like Fig. 8. The two sets of stars can be identified because the stars of the second will appear double or as dots with short trails beside them. The trails of the satellite can be identified from the angle they cross the plate but the second trail may be broken for a second or two before it reaches the plate centre if preferred. This method has the disadvantage of increasing the plate fog. (It is worth mentioning that HPS can be exposed for at least 40 min. at f/2·5 when the sky is really dark and free from scattered light.)

(*c*) This third method is more economical where wide-angle lenses are being used together with larger plates. The satellite is allowed to trail right across the plate and breaks are made at intervals and timed. Fig. 9

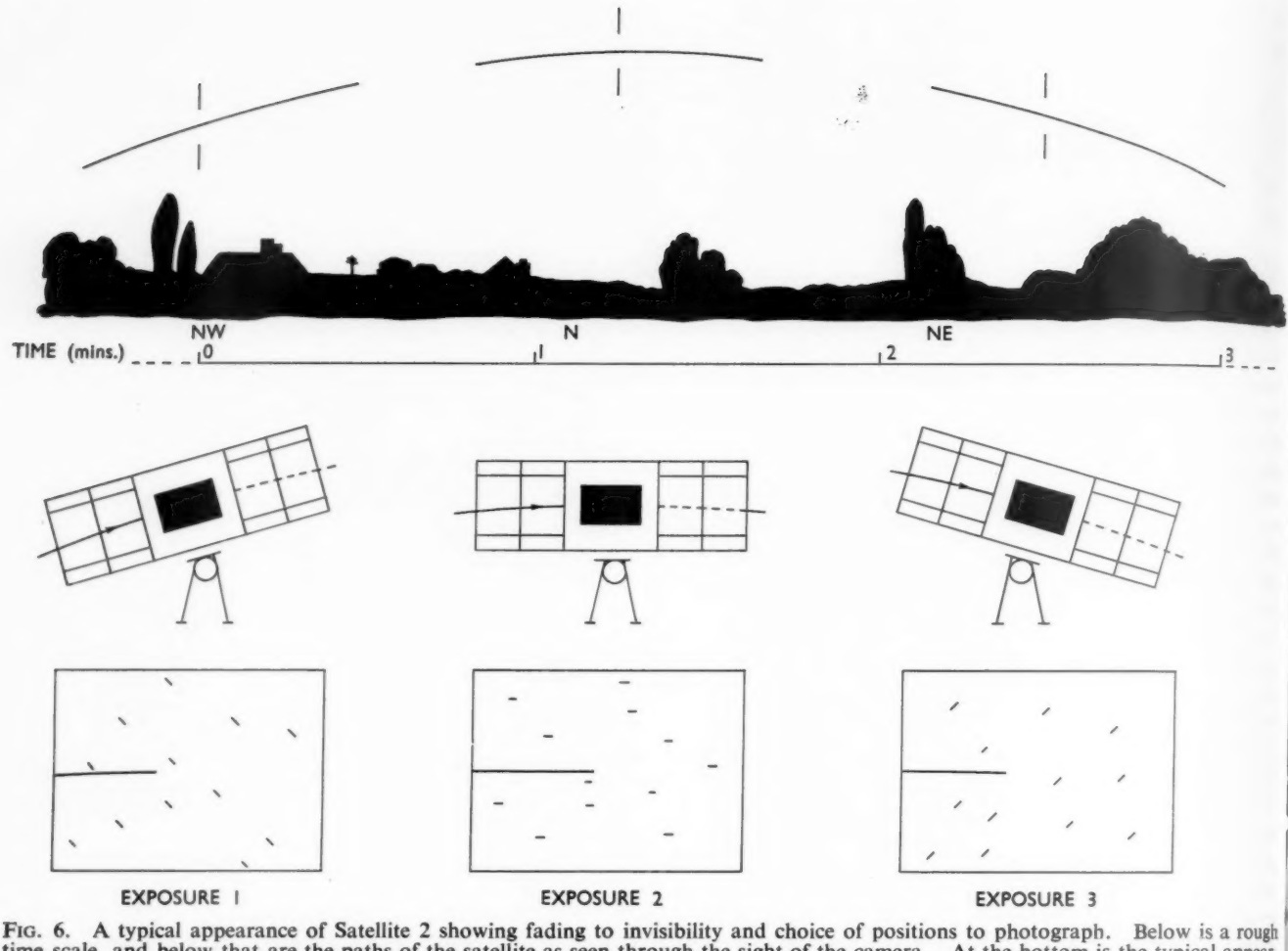

FIG. 6. A typical appearance of Satellite 2 showing fading to invisibility and choice of positions to photograph. Below is a rough time scale, and below that are the paths of the satellite as seen through the sight of the camera. At the bottom is the typical appearance of each plate showing the termination of the trail at the plate centre. This corresponds to the disappearance of the satellite at the right of the field of view of the sights

shows the general appearance of a plate taken in this way. A satellite may take from one to two minutes to cross a whole-plate with a 5-in. focus lens and if the sky is too bright to allow such a long exposure, the breaks may be lengthened at the expense of the trails without any change in procedure.

It is important that when the exposure is commenced no vibration is set up in the camera. For a simple box camera there is no need to provide a shutter at all. A loosely fitting cardboard cap can be made that will cover the front end of the camera completely. At the start of the exposure this is removed gently and held in front of the camera for a few seconds before being slid aside to allow the light in. This prevents vibration and is recommended even when a built in shutter is available. To terminate the exposure the cap, or better still a large piece of dark carboard, is swung swiftly in front of the lens and the cap replaced over the front end of the camera. The cardboard may then be taken away. With practice the covering up of the camera lens can be accomplished in a fraction of a second; more difficult is the timing of this event with sufficient accuracy.

Timing of Observations

Observations of satellites are required to a minimum accuracy of 1 sec. and an optimum accuracy of one-tenth of a second. It should be pointed out that observations of lesser accuracy may well be of use in cases where the satellite's orbit is not well known. Such observations should be communicated in the usual way: rather these figures are the accuracy that should be aimed at and achieved if at all possible. All observations should give the observer's estimate of the accuracy attained. What is important is that the accuracy should not be overestimated and it is better to give a pessimistic estimate of this accuracy than to give an observation to a greater degree of accuracy than is, in fact, justified.

Times should be given in Universal Time (U.T.) which is identical to G.M.T., which will mean making the appropriate allowance for British Summer Time when this is in operation. The most accurate means of getting U.T. in this country is from the B.B.C. time signals which are to be preferred to the G.P.O. Speaking Clock. Continuous time signals are sent out from the U.S.A. and Canada and those from the United States are

regularly picked up in this country by some observers. Observers who have short-wave sets are advised to try to receive them.[7] It might be possible to build or adapt some ex-Government radio apparatus to operate on the required wavelengths at comparatively small expense. The U.S.A. time signals are broadcast on the following wavelengths: 120, 60, 30, 20, 15, and 12 metres throughout the 24 hours. The time is announced orally every 5 min. and the seconds are marked by seconds beats. A Morse code statement in Universal Time precedes the announcer's voice introducing the next 5-min. period. All other times are given in Eastern Standard Time (U.T.-5 hours).* The Canadian ones are similar in most respects, the wavelengths being 90, 41 and 20·5 metres.

Where these continuous time signals can be picked up clearly no difficulty is likely to arise although observers should note that they are off the air for a few minutes at certain times of the day. Headphones may be worn in which the observer can hear the pips and time announcements. The time of the beginning of the minute before the start of the exposure is noted and the pips counted until the temination of the exposure.

Most observers will have to make do with clocks or watches used in conjunction with the B.B.C. time signals. The watch (or clock) to be used should be the most reliable available and should be checked against the time signals at least twice a day, for instance, at 07·00 and 23·00 U.T. A record should be kept of the amount by which the watch is fast or slow of the time signals by noting the time shown by it at the sixth pip. The rate of gain or loss per hour over a period can then be obtained and it should be reasonably constant. The watch should not be put right each time it is checked as this is unnecessary and will lead to mistakes. The time should also be checked against the time signals as soon before and after an observation as possible. The correction to the time of observation is made in the following way:

	h.	*m.*	s.
Instant of terminating exposure (watch time)	19	14	16
Watch fast of Time Signal at 18·00 U.T.		1	5
	19	13	11
Rate of gain 2 sec./hr. (approx. 1 hr.)			2
Time of observation (end of trail) in U.T.	19	13	9

The actual noting of the time of observation is simplified if an assistant is available to note the time from the watch as the observer calls out. Where the observer is alone there are several methods of recording the time of which only a brief mention may be made here. The most accurate method is to use some sort of chronograph, a device that records the passage of time as a series of marks on a moving chart (usually in ink on a moving paper band or drum). This type of instrument also has a means whereby the observer may make another mark by remote control alongside the time marks. When the time marks are controlled by a very accurate clock or by radio time-signals, the time of the observation may be measured very accurately as a linear distance on the chart between two time marks. Such an instrument could be constructed to give good results at least over a short period of time. If a tape recorder is available this may be used in a similar way, the beats of a clock or continuous time signals being recorded directly on to the tape together with the observer's time of observation which may be in the form of a "click" or more simply a verbal announcement. The time marks are important even if the time is read on to the tape before and after observation, because the speed of a tape recorder may vary over quite short periods due to various reasons. This may lead to an error of several seconds.

FIG. 7. The second Russian satellite photographed on Dec. 2, 1957, 05.50 U.T. in the northern sky. The satellite was moving at about ½ deg. per sec. and the exposure was about 25 sec. The satellite (which was moving from left to right) was about 2nd magnitude when this photograph was taken with the camera shown in Figs. 4 and 5, but it faded and disappeared three times during its passage across the sky. Two other photographs were taken at the other peaks of brightness

Amongst the best methods is one of the simplest. The observer wears headphones in which he hears the pips of a contact breaker controlled by a clock or the beats of a clock from a microphone. Contact breakers giving ½-sec. beats were available from Government surplus stores and these can be fitted up with headphones and a battery for easy mobility. The observer finishes the exposure on a pip and then counts the pips until they coincide with a minute on the watch. The time by the watch is easily obtained and the usual correction to U.T. made. This method can be done almost subconsciously and with complete accuracy after a little practice.

The timing of observations is really more difficult than obtaining positions for them; and as a satellite close to the Earth will be moving at a speed of about five miles a second, it can be seen that time and position are far from independent. A good accurate technique is well worth the effort of acquiring.

* Full details of the United States continuous time-signals can be found in *Sky and Telescope* (see References). In case of difficulty, the writer will gladly supply such information as is available to him.

Reporting Observations

It will have been realized that the method of obtaining a satellite's position is to measure the instant when it appears in a certain direction in space as seen from a known position on the Earth's surface. Timing has been dealt with already. Position must be measured with

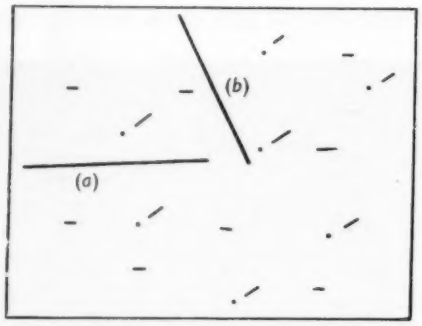

FIG. 8. The general appearance of a plate taken with two exposures on the same plate. The trails are identified by the angle at which they cross the plate and the star trails by the accompanying longer trails for the second set. (In this case (a) is the first trail and (b) the second)

reference to the star images on the photographs. It will be sufficiently accurate to compare the plates with large-scale star charts without going into calculation of precise positions as in positional astronomy. Where no charts are available, prints could be sent to the co-ordinator for measuring. Such charts as the Bonner Durchmusterung (scale 20 mm. to 1°) or the *Beyer-Graff Stern-Atlas* (scale 10 mm. to 1°) are really required, but these are relatively expensive; however, as a long term project the latter would be a sound investment. The trails of the satellites are best drawn on a piece of tracing paper put over the chart allowing the position of the end point to be read off. The position is obtained in terms of right ascension and declination and it should be noticed that these charts are drawn for the epoch 1855·0, so that allowance for 103 years precession must be made.* This correction is easily obtained with sufficient accuracy from tables, such as the one in *Norton's Star Atlas*[8], which is invaluable to observers and will provide rough positions to within about half a degree with careful plotting.

Reports should show the following information:

Date and time (in U.T.) to nearest second.
Right ascension and declination and Epoch.
Place of observation, lat., long. (nearest second of arc.) or map reference from Ordinance Survey map, and sheet number.
Approximate height above sea-level.

* Errors in position of over half a degree may otherwise result.

Means of observation (visual etc.) estimated accuracy of time and position, estimate of brightness is also of interest.

Conclusion

It has already been stated that the observation of satellites is of vital importance and that photographic

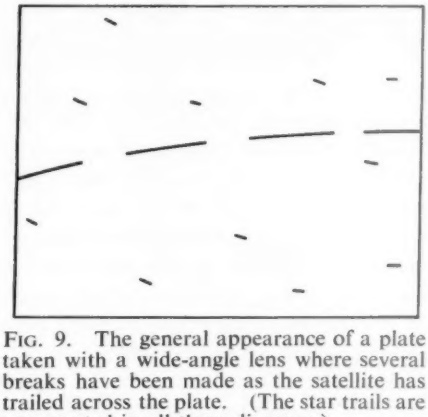

FIG. 9. The general appearance of a plate taken with a wide-angle lens where several breaks have been made as the satellite has trailed across the plate. (The star trails are exagerrated in all these diagrams)

observation may offer the widest scope for useful observations to be made by relatively inexperienced observers.[9] Considerable space has been taken up here in trying to bring out what are, to the writer's mind, the essentials of satellite photography. They may be summarized as accurate adjustment of the camera, a steady mobile mounting and a good observing technique. It is hoped that many members, especially those who are already photographers or astronomers, will be encouraged to take up this interesting and useful work.

Once they are getting their own results they will be able to devise their own techniques and equipment to the advancement of this new branch of astronomical observation, the photography of artificial Earth satellites.

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Satellite ephemerides, observation notes and copies of the "Satellite News Bulletin" can be obtained from the B.I.S. Secretary on sending a foolscap reply-paid envelope.—ED.

White Sands

By FRANK B. POLLARD

About 50 miles north of El Paso, Texas, lies the White Sands National Monument, a 250 square mile area of white gypsum hills, set aside by the U.S. Government because of its unusual natural beauty. Part of the National Monument lies within the 100 mile long and 40 mile wide U.S. Army Ordnance Missile Test Centre, White Sands Proving Grounds (W.S.P.G.). The proving ground is an integrated range used by the U.S. Army, Navy, Air Force and in small numbers, Marines.

The area, before 1945, was an isolated desert inhabited by wild life and stray cattle. Even today the deer, coyote, rattlers and assorted reptiles, and an occasional mountain lion are found within this yucca, mesquite and cactus covered wasteland. The proving ground itself lies in what is geographically known as the Tularosa Basin between the Sacramento and San Andres mountain ranges of south-west New Mexico, and is the heartland of United States high altitude research and intermediate-range weapons testing.

In the southern section of the range is located the launching area used by the U.S. Army and the U.S. Navy, while approximately one-quarter of the way up-range, to the east, lies Holloman Air Development Centre (H.A.D.C.), the Air Force facility. Most firings take place in the southern section of the range and the flight is north into open country. Headquarters for W.S.P.G. administration, personnel and living quarters are found some 8 miles from the actual launching sites, and are located in the south-west corner of the range backed up by the barren Organ Mountains.

At the inception of rocket and missile testing at W.S.P.G. it was known that the range would some day grow too small to contain the test vehicles or "birds" as they became better, faster and increased their range. This knowledge has become fact and as a result over-water proving grounds off the coast of Florida and California are being used to test long-range vehicles. The greater amount of testing, however, continues at White Sands and will for years to come.

A great deal of consideration is given to range safety both regarding personnel on the range and the populace living beyond the range boundaries. Several incidents precipitated research into range safety. The first was the erratic flight of a rocket, which instead of going north as it was programmed, swung south and after a short flight impacted in Juarez, Mexico. The second incident was a rocket which got out of control and impacted near the town of Alamogordo, New Mexico. Other less spectacular incidents have occurred. It is now a rule at White Sands that no missile or rocket shall leave the range. A great deal of research and money has gone into range safety with excellent results. By means of a complex system of devices coupled with a fine monitoring system, the flight of a test vehicle can be terminated remotely by closing fuel valves, cutting feed lines, or by causing the vehicle to explode or disintegrate harmlessly over the barren wastes.

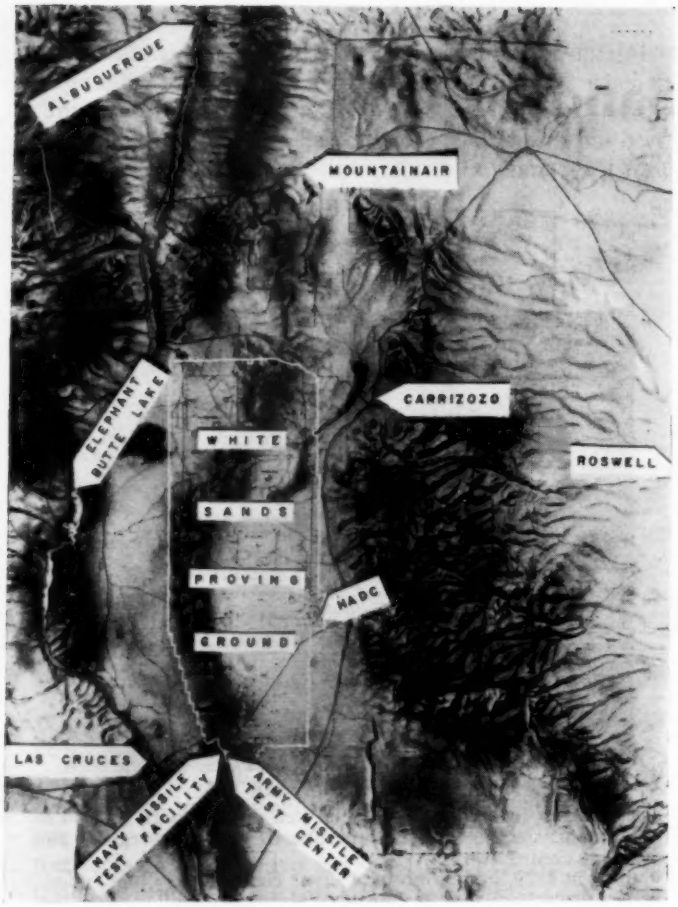
Safety for personnel on the range is built-in. The blockhouses, which are the nerve centres during all launchings, are reinforced concrete structures with 10-ft. thick walls and a roof of 27 ft. thickness—designed to stand the impact of any missile in a direct hit without damage to the personnel inside. From the blockhouse the missile or rocket vehicle is controlled and monitored. Control, communication and power lines leading to the launching platforms are located underground and direct communication with any of the field stations and radar installations is immediately available.

FRANK B. POLLARD

The name of Frank Pollard will be well known to all readers of *Spaceflight*, since he has become one of our most regular and welcome contributors.

Born in 1923, he was brought up at Hempstead, Long Island; he went to school at Ohio Northern University, and then studied aeronautical engineering at New York University. During the War he served as a pilot with the U.S. Air Force, and after his operational tour became an instructor. He is still an active reservist.

Nowadays he is engaged upon technical work concerning missile research and allied fields, and is an accredited correspondent of the Department of Defence. Contributions by him have appeared in many journals and other publications; we look forward to hearing more from him in the future.



Map of White Sands Proving Grounds and outlying areas. The range is 100 miles long and 40 miles wide. At the bottom of the picture, two separate launching areas are located for the Army and the Navy. About one-quarter of the distance uprange is the Holloman Air Development Centre—which is part of the proving ground and where the Air Force launches its missiles on the range. White Sands Proving Ground is an integrated range shared by the Army, Navy and Air Force. The Marines are also active in Lacrosse and Hawk missile firings

(*U.S. Army Photograph*)

The landscape at White Sands Proving Ground is dotted with a variety of test stands, gantry cranes, radar saucers, cameras, phototheodolites, telegraph poles, miles of wire and a number of telescopic mirrors, all to watch and report the progress of the latest "bird" to be fired.

This is the proving ground of firsts. The V-2s captured from the Germans were tested here, the WAC-Corporal climbed out of W.S.P.G. 250 miles into the upper atmosphere and held the altitude record until late this year. The Nike was proved here and the Viking, the Dart, the Matador, the Hawk, the Corporal and, in fact, almost every missile or rocket in the United States arsenal has been a first at White Sands.

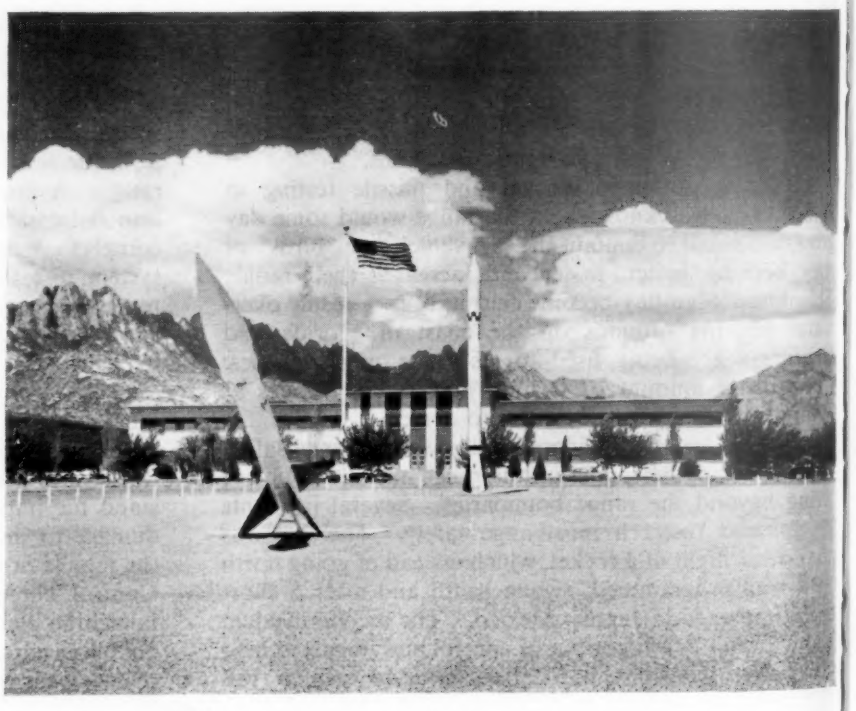
It has been stated that the sky above the proving ground is the most widely explored piece of upper atmosphere in the world. And this is true. We, how-however, still know little of the nature of the upper atmosphere even with the mass of data recorded each day at White Sands, Patrick Air Force Base and other sites throughout the world. The location at W.S.P.G. is almost perfect for missile testing. Targets can be shattered by rockets and missiles with only the loss of a batch of cactus or a clump of mesquite. The clear air of the south-west is perfect for visual and optical tracking. Occasional sand-storms or dust-storms disrupt the activity but for the most part the sky is clear most of the year.

In a typical launching, the missile or rocket vehicle is brought into the fuelling area where men in rubberized protective clothing exercise extreme care in fuelling the vehicle. An extensive pre-flight check of electronic,

(*Right-hand photograph*)

In a picturesque setting are located the head-quarters buildings of the White Sands Proving Grounds—towering in the background are the bleak and beautiful Organ Mountains

(*U.S. Army Photograph*)



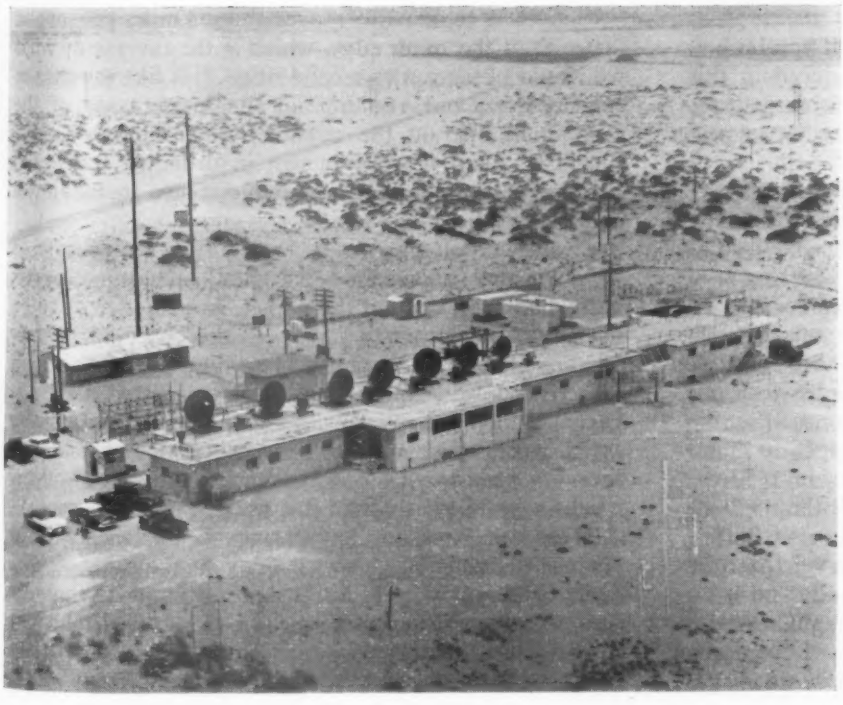
hydraulic and instrument systems is accomplished. The stations up and down the range are active and all roads leading into the range are sealed off. In the blockhouse the pre-planning takes shape and the team of men make last minute checks on instruments and communications. Outside the final preparations for flight are being made and the gantry is rolled out of the way. The area is cleared. Suddenly it is all quiet and the count down in progress. At Zero the missile stands on its tail, almost without movement, a great flame issuing from the combustion. Then slowly it begins its climb, faster, faster with a great roar it moves spaceward and suddenly is gone.

The ground instrumentation is alert to signals returning from the vehicle and the cameras, radar and photo-theodolites are tracking. In a few minutes it is over and the men and instrumentation come to a standstill. The data has been gathered, the flight is over and the vehicle is on the Earth again. The cameras, the radar, Doppler and optical instrumentation have tracked it, the telemetering, tape recorders, Geiger counters, spectrographs and other instruments have amassed data for reduction and analysis.

Many research programmes are conducted at White Sands, most of them complex in nature and relating directly to rocketry. At the proving ground you see officers from all the services, space-suited technicians, nondescript engineers and scientists, all with one thought in mind. Better missiles, better rockets for the successful conquest of the upper atmosphere and soon, space.

The Nike-Cajun rocket is a two-stage vehicle employing the Nike-Ajax booster for launching and a Cajun I rocket for the second stage. In order to avoid the high drag region of the atmosphere, the Cajun is designed to coast after the initial launching phase, then fire its motor at about 40,000 ft. Accelerations of 80 times the force of gravity and speeds of 5,600 ft. per second are generally attained. Destined to play a major role in the IGY the Cajun is equipped with tracking devices to measure electron densities in the ionosphere

(U.S. Army Photograph)



(Left-hand photograph)

"C Station," the nerve centre of the communication hookup on the firing range. Seven radar antennæ atop the roof are used in initial tracking of missiles fired from the south end of the range. As a missile progresses uprange, radar stations along the way pick up and track the missile, sending data back to "C Station"

(U.S. Army Photograph)

Saturn

By H. N. D. WRIGHT

An account of the Ringed Planet, perhaps the most glorious object in the heavens

Saturn is one of the five bright planets which have been known and observed since ancient times. The early astronomers saw nothing unusual about Saturn. It was a typical planet, or "wanderer" to them. They noted its dull yellow colour, and the fact that it moved at a more leisurely pace against the star background than the other planets.

It was not until around 1610, when Galileo, the first telescopic astronomer, focused one of his tiny telescopes on Saturn, that astronomers realized that there was something "special" about the planet. It appeared to Galileo, with his small and inefficient instruments, that Saturn had two smaller companion planets travelling with it (Fig. 1), and he came to the conclusion that it must be a "triple planet" system. Imagine his amazement when, a year or two later, the two companions dwindled and finally disappeared, leaving Saturn as a single, approximately round globe. Then, later still, the two "extras" gradually became visible again. Galileo never discovered the true cause of this strange behaviour, because his telescopes just could not reveal the necessary detail. If you look at the photograph of Saturn (Fig. 4), reproduced in this article, from a distance of about 12 ft., it is easy to see how Galileo was deluded into thinking that Saturn was a triple planet.

H. N. D. WRIGHT

The diagram (Fig. 2) shows what happens to give Saturn its vast, gradual change in appearance. It is surrounded by an immense flat ring, which is inclined at about 28° to the plane of Earth's orbit. The ring is in the plane of Saturn's equator, and, in a similar way to Earth, Saturn keeps its poles of rotation in a fixed direction in space. (You all know how invariably the Pole Star indicates True North in this hemisphere of our planet.) Therefore, from our viewpoint, we see the ring system at all angles from edge-on to 28° open in either north or south direction. As an instance, in 1950 the rings were edge-on to Earth, and in 1958 they will be exposing their north face to the full 28°. As Saturn orbits the Sun in about 29½ years, the interval from the rings being fully open in one direction to edge-on is an *average* of a little over 7¼ years. This varies slightly with the speed at which Saturn moves in its orbit. In common with the other planets, Saturn moves fastest when it is closest to the Sun. At the moment astronomers are studying the north face of the rings almost fully open to 28°, but in about 14½ years the reverse will be the case, and we shall be looking at the almost fully open south face of the ring system.

At first glance the rings of Saturn look quite solid and substantial, and for some time astronomers took this for granted. In 1857 Clerk Maxwell demonstrated mathematically that a solid ring could not exist, and proof of this came when an instrument known as a spectroscope was used to show that the inner edge of the rings revolves around Saturn at faster speed than the outer edge. There is not space here to describe a spectroscope in detail, but briefly it is an instrument to analyze the components of any light source, and it can tell us what substances are producing the light, or how the light is modified by absorption. It can also reveal, above a certain limit, whether a light source is approaching or receding, and at what speed. In this case it was found that the inner edge of Saturn's ring system actually moves about 3 miles per second faster than the outer edge, which is the reverse of what we would observe with a solid ring. It is like the case of two athletes, one running on the inside edge of the track, and one on the outside. The outer one must run faster than the inside man in order to stay level, because he must cover a greater distance in making a complete circuit of the track.

Clerk Maxwell also stated that the rings would have to be composed of separate particles, each pursuing its individual orbit around the planet, and this seems to be the only explanation to satisfy all the observed characteristics of the ring system. The rings have a very high reflective power, and it has been suggested that the particles may be covered with frost, or that they may be actual pieces of ice. In any case, the particles are almost certainly very tiny, and a pulverized substance reflects much more efficiently than if it were in larger pieces.

There are three concentric rings in all, each with a distinct character of its own: Ring A, the outer ring, a dusky white or ivory in appearance; Ring B, the middle ring, usually a brilliant white, and more often than not the brightest feature of Saturn; Ring C, the Crêpe Ring, the innermost one, and a difficult feature to observe. It

has the appearance of a faint shading, rather like a veil, inside the B Ring. These rings are well seen on the drawing (Fig. 3), which is by G. Ruggieri, a skilful Italian observer, showing all the features he observed in 1955. Unlike some observers, he did not see a distinct division or gap between Ring B and the Crêpe Ring, but, as he puts it "only a sharp leap in brilliance". There is, however, a wide gap between the Rings A and B which was first noted by Cassini in 1675, and named the Cassini Division. It is 1,750 miles across, and is a permanent feature of Saturn. Another lesser gap exists in Ring A, named, after its discoverer, Encke's Division. This is only seen on occasions in large telescopes, and it appeared to Ruggieri in 1955 as a grey line.

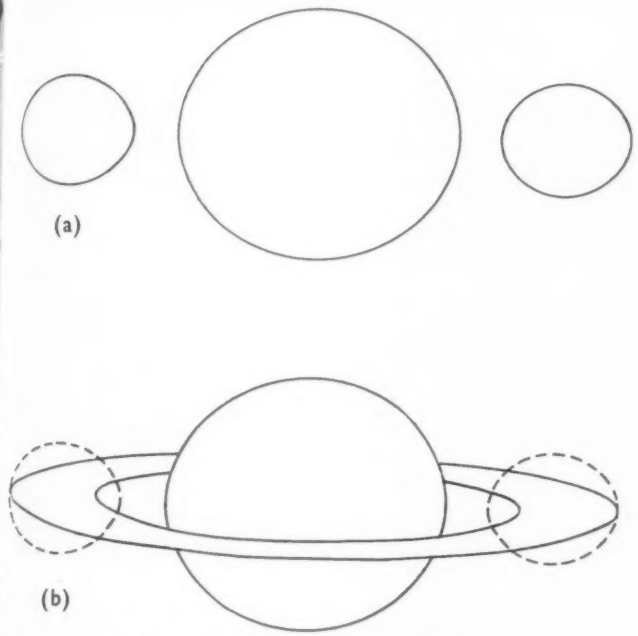


FIG. 1. (*a*) Saturn as drawn by Galileo (1610)
(*b*) Ring system at a small angle gave him the impression of two companions

The breadth of Ring A is 10,320 miles, and of Ring B 16,765 miles. Between the inner edge of the Crêpe Ring and the surface of Saturn itself is a gap of over 9,000 miles, so that the Earth could pass quite comfortably through it.

The Crêpe Ring is translucent, as can be seen from the drawing, allowing the globe to be seen through it. A remarkable observation, made in March, 1920, established the fact that the brightest, and presumably the densest of the rings, Ring B, can also be "seen through" to a limited extent. An orange-coloured star remained visible, though greatly dimmed, throughout the whole of its passage behind the ring system. Also it is known that the rings are fantastically thin. Even though they have a total span of some 170,000 miles, yet their thickness is estimated at not more than 50 miles, and is probably much less than this. (I did see it described somewhere that the rings were only 3 *inches* thick, though what remarkable instrument had been used to arrive at this conclusion was not stated!) The largest circle which could be cut out from a page of this book would just about represent the scale of thickness of the ring system, using the estimated maximum of 50 miles. This explains why, at times when the rings are edge-on to Earth, they appear to vanish in all but the largest telescopes.

You may ask, why should Saturn be the only planet to possess such a ring system? The clue lies in the fact that the rings have the smallest ratio of distance from the centre of the parent planet, bearing the size of the planet in mind, than any other object of satellite nature in the Solar System. There is a distance ratio known as "Roche's Limit", inside which a satellite of solid substance and over a certain size, will be broken up by the terrific tidal force exerted by the planet. This distance is calculated as 2·45 times the radius of the planet. The radius of Saturn's outermost ring is 2·30 radii of Saturn. It is quite possible that, at one time, Saturn had ten satellites, and one of these came within the fatal "Roche's Limit", and was torn to pieces by tidal action. These pieces would further break down by collisions amongst themselves, until we would be left with an extensive swarm of tiny particles revolving in their separate orbits around Saturn. This will be very disappointing news to those people who had hoped to use the ring system as a landing and take-off zone for space-craft!

I must apologize for having gone to such lengths in describing the rings, but it is difficult to do justice to such an amazing appendage. The globe of Saturn is also unique in some respects. You are probably aware that the Earth is not a perfect sphere, but is a little flattened at the poles, the polar diameter being 26 miles less than the equatorial. This represents a compression of 1/297th. If we draw a circle and compress it this amount, it will need very close examination to tell that it is different from a perfect circle. When we observe Saturn, even with a fairly small telescope, it is obvious that the globe is compressed quite a lot. The polar diameter is actually 1/9th less than the equatorial, and this is the most pronounced flattening effect among the planets. Actual measurements are: 75,100 miles equatorial and 67,200 miles polar. This polar compression is a direct consequence of its low density and high rotation speed. Saturn's "day" is only 10¼ hours, which is quite a speed to rotate considering its size, and its density is less than that of water. You have all, I expect, observed how a piece of pumice floats in water. Saturn is near the same density as pumice, and would behave in the same way if we had an ocean large enough to launch it in. This is of course referring to the *mean* density of Saturn. The planet is thought to have a considerable solid core, but this is offset by the vast gaseous mantle surrounding this core. It is rather like the weight of a ship being offset by the amount of air-space in it, thus enabling it to float.

Saturn is second only to Jupiter in size among the planets, and as is the case with Jupiter, the globe which we actually see is the outer layer of a deep atmosphere of unpleasant gases. Such hydrogen compounds as methane (or marsh gas) and ammonia abound in this atmosphere, which is believed to be about 16,000 miles deep! To add

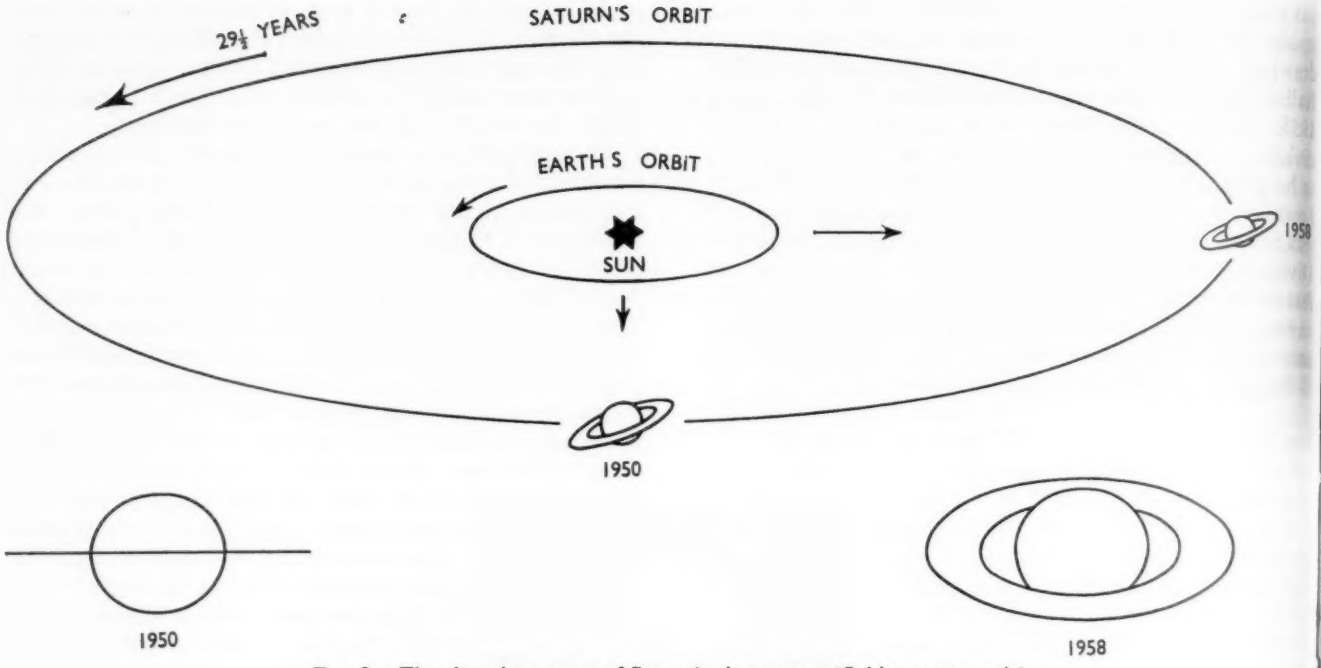


FIG. 2. The changing aspect of Saturn's ring system (Orbits not to scale)

to this unpleasantness, the temperature at the surface of these gases is thought to be as low as — 155° C. Saturn is not a very hospitable sort of world.

The only permanent detail visible on the globe of Saturn normally is in the form of two dusky belts, one a little north of the planet's equator, and one a little south. They are both parallel to Saturn's equator, and the Northern one is seen on the drawing (Fig. 3). I have myself seen the Northern Equatorial Belt with a telescope having only a 3-in. diameter lens, so they are quite conspicuous. Other belt markings are seen occasionally in larger instruments, two more faint ones being recorded on Ruggieri's drawing. He has also recorded the Equatorial Band, a very delicate feature, which is also only seen on occasions under very good conditions. It is reproduced by Ruggieri as a broken line just about on the equator of the planet. It must be remembered that this is a composite drawing, and he did not see all these features at one and the same time. Other details on Saturn, such as spots, are very rare. The "humps" on the main belt in the drawing are usually short-lived phenomena and of no use in checking the rotation of the planet. The most conspicuous spot of recent years was that discovered by the late Will Hay, an amateur observer otherwise known in the entertainment world. On August 3, 1933, using a 6-in. aperture telescope, he found an oval white patch on the Equatorial Zone of the planet, which persisted for about five weeks. During this period many skilled observers watched this marking, and they co-operated in further refining our knowledge of the rotation of Saturn on its axis. The method used is for each observer to estimate as accurately as possible when he considers the extremities of the feature to be on the centre line of the visible disk. By taking an average of all these estimates, the rotation period can be deduced to quite fine limits. On this occasion observations confirmed that Saturn rotates in 10 hr. 14 min. *at the equator*. Due to the fact that we are looking at the surface of a vast ocean of gases, the rotation period is not the same for any position on the planet, but becomes longer as we approach the poles of rotation. Because of the lack of definite markings on the globe of Saturn, much more information has still to be gained about the rotation of other zones of the planet.

You will notice that the photograph (Fig. 4), taken with the world's largest telescope, fails to show any of the fine detail on the planet or rings such as we see on Ruggieri's drawing. It is not generally realized by the majority of people that most work on planetary detail is done just by direct observation at the telescope, and drawing what the eye can detect. Even though a great deal of work is going on to perfect photographic methods, they cannot at the moment supersede the visual observer working with a trained eye, and a degree of care in drawing what he sees, in the matter of planetary detail.

As previously mentioned, the diameter of the globe is 75,100 miles through the equatorial region, and this is roughly 9½ times the Earth's diameter. If you make a note of this number, 9½, it is a great help in remembering some of the more important statistics of Saturn. For instance, the mean distance of Saturn from the Sun is 886 million miles, which is almost exactly 9½ times the Earth's distance. Next take 9½ and multiply it by 10, and we have the number of times Saturn is more massive than the Earth, 95. Then add 20 to 9½, and we have the number of years which Saturn takes to complete a revolution round the Sun, 29½. Finally, if we quite unofficially count the ring system as half a satellite, then Saturn has 9½ moons!

FIG. 3. Saturn as seen by G. Ruggieri, 1955

All these moons have been given quite attractive names. First comes Mimas, revolving only 30,000 miles outside Ring A, followed in order outwards by Enceladus; Tethys; Dione; Rhea; Titan; Hyperion; Iapetus; and Phœbe. The last-named, which was discovered by Pickering in 1898, is at a distance of 8 million miles from Saturn, takes 18 months to go round once, and goes round in the opposite direction to all the others! Eight of these moons are believed to be quite small bodies, ranging from less than quarter to about half the diameter of our Moon. The "odd moon out" is Titan, which is of planetary size, larger than Mercury and smaller than Mars. Titan is estimated to be 3,550 miles in diameter, and is thought to be surrounded by an atmosphere of similar unpleasant composition to its parent planet. It is also the only satellite which is visible in a small telescope, and can be detected fairly easily with only a 3-in. aperture lens. All but one of the brighter satellites have their orbital paths close to the plane of the ring system, and therefore their orbits can never appear to us as circles, but are always considerably oval or elongated, varying with the aspect of the rings. It follows that the best time to look for Titan with a small instrument is when it is near the east or west extremities of the oval. Titan revolves around Saturn in 16 days, and is therefore at the east or west extremities of its path at intervals of about 8 days, and at these times is furthest from the glare of Saturn and its rings. All of Saturn's moons can be visually detected in larger telescopes, and it is a wonderful spectacle to see the planet surrounded by this glittering retinue. At times when the rings are near edge-on to Earth, it is also possible to see several of the moons spaced along the thin line of the rings, rather like beads threaded on a silver wire.

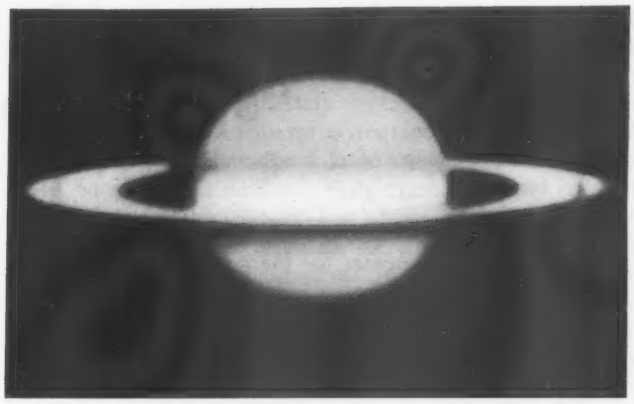
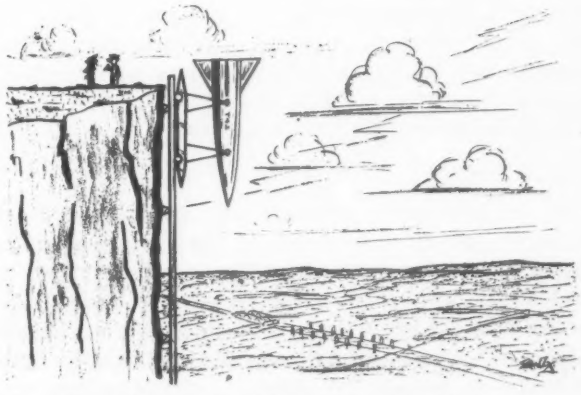


FIG. 4. Photograph of Saturn. 200-inch reflector—*courtesy Mt. Wilson and Palomar Observatories*

Saturn is at its worst observationally to British observers at the moment, and as the planet moves along so slowly through the constellations it will be some three or four years before the position improves very much. Not only is it low in the sky (only 16° above the Southern horizon), but is visible during the short summer nights, with observing time cut down to the minimum. Nevertheless observers will be studying the planet at every possible opportunity, and people are still badly needed for Saturn observing. But even if you have not the time or the equipment for this work, have a try at locating Saturn against the star background. This year it is some degrees east of the bright orange star Antares, in the south at about 10 p.m. in July, and it will be interesting to compare the yellow, steady light of Saturn with the orange, scintillating light of Antares. If possible, have a look at Saturn through a small telescope. It is a rewarding spectacle on a good night, and a sight never to be forgotten.



"Something to do with an optimum orbit . . . "

"Spaceman Overboard"

By J. C. GUIGNARD, M.B., Ch.B.

Present-day schemes for the construction of large orbital vehicles are based upon the manual assembly of prefabricated sections in space. This paper reviews generally some of the physiological factors involved in this type of work and it is suggested that the difficulties of free flight by men in simple "space-suits" may be prohibitive.

Introduction

The evolution of interplanetary flight will sooner or later raise the problem of establishing orbital vehicles whose size, weight and structural limitations prevent them from being fired into their orbits in one piece. Among their many functions, large satellite aggregates, or "space-stations", will probably be necessary as bases for the refuelling and even the construction of long-haul interplanetary craft and expeditionary orbit-to-surface ferries. Many elaborate design studies have already appeared in the literature, the majority of which are based upon the fitting together, in orbit, of prefabricated sections. It is fairly certain that these parts cannot be assembled by remote control but will have to be man-handled by crewmen in space-suits.

Even the more erudite accounts of satellite-building are often illustrated by artists' impressions of confident, helmeted artisans heaving, hammering, welding and wiring against an awe-inspiring background—usually of the North American continent. But just how easy will such work prove in practice? In case the satellite-mongers are taking the human factor too much for granted, it seems worthwhile reviewing some of the difficulties likely to present themselves.

Orbital Dynamics

In the first place, although the artists' impressions probably convey a fair idea of the various sizes and shapes of metalwork which will have to be handled, it is not so easy to appreciate the formidable masses represented or, more important, the small amounts of residual differential velocity which even the most skilful orbital technique is unlikely to avoid. Everything floating in space, although weightless, will have exactly the same mass as it has on Earth. Discounting friction, it will be virtually as difficult to push a ton of equipment about in free-fall as it is to roll a car on a level road—and just as hard to bring it to rest. Anyone who has had an arm trapped by a heavy boat nudging a jetty will appreciate the reality of mass; and if two massive sections of a satellite were allowed to meet with even a few inches per second of excess velocity, then not only is there a likelihood of damage from the impact but a man caught between them would probably have his career in astronautics cut short. A very high degree of judgment and dexterity will be called for in marrying heavy sections which are to be mechanically joined—and which must necessarily be brought to rest at the critical moment. Any mistakes may be dearly paid for and it is perhaps merciful that space is soundless, for otherwise the heavens might resound to the oaths of welders and the staccato gunfire of shearing bolts. It would probably be as well if the trainee astronaut spent part of his apprenticeship as a rigger in a big engineering yard, where he could really learn the "feel" of large and potentially unstable masses of metal!

It is commonly supposed that not only will spacemen propel themselves from place to place by small reaction motors, but will range far and wide in the environs of their ship, rounding up and assembling several scattered components of the satellite. The reaction guns illustrated in many drawings and films are sometimes strategically fastened, reasonably enough, to a harness, but at others are regrettably brandished like a pistol or fire-extinguisher. There are several pitfalls here, not the least of which is that in free-fall a man will have no stability at all, unless his equipment includes some form of gyro-stabilization. The position of the centre of gravity of the human body is rather indeterminate, depending upon posture and upon the weight and distribution of extraneous equipment. Unless the resultant thrust of the driving jet or jets passes exactly through the centre of mass of the man-space-suit system, their use will produce spin.

Rotation at perceptible rates (particularly in conjunction with weightlessness) is likely to produce disorientation which may in turn result in the man losing control of the situation. As spin in the vacuum of space will be completely undamped it will accelerate as long as the eccentric force is applied and persist until annulled by thrust in the opposite sense. It is conceivable that a gross mishap could produce a rate of tumble which was physiologically dangerous.* It seems very unlikely that stabilization of a man in the conventional, comparatively form-fitting type of pressure suit so often envisaged will be easy or even feasible, if he is to carry out independent

* A six-foot man spinning end-for-end at 80 r.p.m. experiences about 6 *g* negative at forehead level and 6 *g* positive at his feet. The tolerance time for this is but a few seconds, the symptoms being comparable with those of 3 to 4 *g* negative in a linear field. Even if spin of this severity is stopped before circulatory effects become serious, it in any case produces residual mental confusion and disorientation which can last for some minutes.[1]

flight in space. Probably, the "space-suits" used for orbital construction work will be in reality rather massive and rigid capsules, including a gyroscope as part of their essential survival equipment and from the interior of which the operators perform their manipulations by means of counterbalanced robot hands. The development of such a "suit" will be a major project in itself.

Rotation apart, the fineness of control called for in accelerating and decelerating the "space-capsule" as it moves from one section to another has already been hinted at. The man inside it, unless effectively restrained by a safety-harness, risks injury if due to some error he collides with other equipment or is fetched up short by his tether at even a few feet per second. Any incapacitating injury under the circumstances may mean a fatality. If man proves to be incapable of safely piloting his personal transport in space, a "black box" will be required to handle all commuting other than local inching or trolleying along guide-lines. It is desirable in principle to link all the components awaiting assembly on a "site" by cables, even though this represents an expensive addition to the total payload. Apart from preventing accidental loss of sections, such a network would serve several incidental purposes including the equilibration of adventitious electrostatic charge between units and the "clip-on" stowage of loose tools and smaller pieces of equipment. The cables could also carry a system of lights which may conceivably play an important rôle in providing a visual frame of reference.

It will be incumbent upon satellite architects to keep the number of operations in assembly to a minimum and to arrange as far as possible for large aggregates to be built up from a single core, rather than to crystallize upon several separate foci which later have to be linked. Any manœuvres calling for long free flights should be avoided and all crewmen should whenever possible remain closely attached to their units. Incidentally, although scenes depicting astronauts tramping about the surfaces of their vehicles still appear in reputable publications, magnetic boots are mentioned here only to be dismissed. They will not simulate body weight and in any case will be of little value if space-vehicles are to be sheathed in plastics and non-ferrous metals.

Survival

The physiological requirements of life-compartments in space-vehicles are now widely recognized and will not be reiterated in detail in this paper. Suffice to say that a closed-circuit personal capsule, or space-suit, in which a man can work for prolonged periods in space must provide an adequate oxygen tension, air-purification, pressurization to at least 4½ p.s.i.* and efficient temperature regulation. If, in addition, it is to include driving and stabilizing units, communication and mechanical handling equipment, a variety of monitoring and warning devices and possibly stored power, it is obvious that the whole outfit will be of great weight and complexity.

* The minimum level which will prevent decompression sickness[2]. Strictly, this should read 4½ p.s.i. absolute.

The environmental problems of a personal capsule are generally the same as those of a large cabin but some of them—ventilation, for example—are more critical. The difficulties of adequately ventilating a small capsule and the weight of apparatus required will be proportionately greater than for a large cabin. If the capsule is to be self-contained, not only must it supply oxygen at a minimum tension of 3 p.s.i. and eliminate waste gases, but must also circulate or vent the air at a rate sufficient to keep the temperature and humidity about the man at comfortable levels. On long sorties, the hazard from any accumulating noxious fumes (for example, hydraulic and coolant fluids or body gases) reaching toxic concentrations could become more acute and would be less easily detected and dealt with by an isolated man in a little capsule, than in a large life-compartment.

Although the chances of meteoric penetration of a small unit are much less than for a large vehicle of the same skin-thickness (in proportion to their projected areas), the consequences are much more likely to be disastrous. The impact itself may well be fatal and, because the rate of loss of pressure is proportional to cabin volume, decompression of a small capsule will be extremely rapid in comparison with the escape of air from a large compartment through a similar puncture. It is important to remember that the time of useful consciousness following total decompression is only 5 to 7 seconds and that rupture of a space-suit or pressure-capsule is unlikely to be survivable. The belief is held by some enthusiasts that because a man can draw and hold a deep breath for a minute or more, an experienced astronaut will be able to scramble to safety in emergency, or even make brief excursions into space without protection, living upon the oxygen held in his lungs and bloodstream. This is of course fallacious, as it is quite impossible for a man to maintain atmospheric pressure within his chest against a hard vacuum outside. All air would burst from his lungs and, since the oxygen gradient between his alveolar air and the blood would be reversed, the time of useful consciousness would again approximate to the time which it takes the blood to travel from the lungs to the brain.

Radiation

At a given distance from the Sun, the absorption of solar radiation by a body in space depends upon the area which it presents to the Sun and, assuming equal absorption factors and equivalent dark-side losses, the heating effect upon a small object will be proportionately greater than on one of larger volume. If spacemen are intended to work in the direct glare of the Sun, the demands upon the heat-regulating mechanisms of their capsules will be heavy. (The dangers of sunlight in the visual and ultraviolet ranges are reviewed in the next section.)

The biologic effects of primary cosmic radiation are not yet established, nor has the intensity of this radiation beyond the atmosphere been estimated with any certainty. Unless these rays turn out to be prohibitively harmful,

it is unlikely that any form of shielding will be used in space-vehicles. If this is so, the flux through a man in a space-suit outside a ship will be no greater than he receives inboard.

Vision

The visual problems already encountered in high-altitude and night flying will become intensified when men attempt to use their eyes in space and, until many more people have flown at much higher altitudes, it is difficult to predict with any certainty just how useful or even safe it will be to look out of the windows of space-ships.

The dangers to vision arise from exposure to the full range and intensity of solar radiation, either received directly or reflected from local structures and planetary surfaces. Apart from the sheer discomfort of intense glare, the unprotected eye risks damage from radiation in both the infra-red and ultraviolet ranges. These rays are normally largely filtered out by the atmosphere and their full intensity in space is not yet known. Short-term heavy exposure to infra-red radiation (as from atomic heat-flash, or looking directly into the Sun through a telescope) can produce a retinal burn, while long-term moderate irradiation leads to the type of cataract sometimes seen in furnacemen: this damage is permanent. Ultraviolet light can blister the skin, as everyone knows. It can also produce a temporary but very painful and incapacitating burn of the cornea and, as this injury can occur at low altitudes (snow-blindness), it is almost certain to result from even a few minutes' exposure to unattenuated solar radiation. Even if the eye is directed away from all bright sources, ultraviolet light striking the eye obliquely gives rise to a fluorescence[3] in the lens which might become significantly troublesome in space, as it will make the aphelioscopic darkness even more impenetrable.

A filter will therefore be obligatory for all transparencies through which crewmen are likely to come face to face with sunlit surfaces. Some ingenuity will be needed to devise one which stops all harmful rays while preserving a moderate and neutral density cut-off in the visual range. (This last is necessary if planetary surfaces are to be inspected and coloured lights interpreted.) It would probably be necessary to develop an automatic visor for space-capsules which will allow normal vision under dark conditions but snap on photoelectrically if the field-brightness reaches critical levels.

Assuming that it can be made safe to look out of the window in space, will our unaided eyes enable us to do anything more than merely enjoy the view? The answer is probably very little, because all visual task-performance is likely to be grossly impaired in space. There will be a loss of normal discrimination and depth-perception (for reasons discussed below), added to the probability of misleading sensory information arising from weightlessness and the lack of a substantial frame of reference.

When a strange object is seen at ground level, we can normally form a fair estimate of its size, shape, distance and relative motion. Discrimination and depth-perception depend not only upon clear vision and the use of paired eyes, but also upon several ancillary factors (see Appendix). We refer the unknown to other objects in the field of vision (Fig. 1) and its interpretation is based upon perspective, parallax, comparison with objects of known size and attitude, the presence of shadows and intervening haze. This is an essentially automatic faculty, acquired in childhood. In space, most of these ancillary "cues" will be lost, visual acuity may be diminished and external reference of very doubtful value.

It will be extremely difficult to judge the size and distance of an isolated bright object in space (Fig. 3). Highlights will be intense and shadows profound, irrespective of distance, and—because it is isolated—the object will look further away than it really is, by the same illusion that the Moon appears smaller at the zenith than when seen against trees or buildings.[4] Parallactic displacement of the object against the stars (if they are not obscured by glare) or other bodies will be virtually impossible to interpret, because it will depend upon the relative motion of both observer and target with respect to the background.

Weightlessness *per se* should not adversely affect the optics of the eye. (It is sometimes suggested that tears will accumulate under zero-g. In fact, they are drawn into the lachrymal ducts by capillarity and there is no evidence that the circulation of ocular fluids will be hampered by the lack of gravity.) But under certain conditions in free-fall there is a strong possibility that the lack of rapport between the visual picture and the information sent to the brain by the vestibular organs may produce disorientation.

Rotations or linear accelerations lasting more than 2 to 3 seconds stimulate the vestibular organs and, if the stimulus is intense enough, eye-movements are reflexly induced. It is well known that in flying, when external reference is diminished, the messages sent to the brain by these organs can be very misleading—even to the experienced aviator. For example, the eye-movement induced by forward acceleration can produce an apparent downward shift of the scene ahead, leading the pilot to imagine that he is trimmed nose-up (the "oculogravic illusion" of Graybiel).[5] This type of disorientation would be greatly intensified in the emptiness of space and would be one of the chief factors militating against astronauts successfully flying their personal capsules on random flight-paths without some form of guidance.

There is already a fair amount of evidence that when a man is largely cut off from the frame of reference of normal sensation (as in the stillness and silence of balloon ascents or the monotony of high-altitude straight and level flight), he tends to become "abstracted", or withdrawn from his surroundings, and may report a loss of his sense of time and space. This condition might become troublesome in isolated astronauts floating in the void and a weightless man drifting in a silent capsule —with nothing to look at but an unmoving panorama of

starry black sky—would be reduced to a very low ebb of sensory awareness. Under these circumstances, any visual or vestibular stimulus will have a diminished and possibly confusing effect. If, say, the Moon appears abruptly somewhere beyond his feet, he may—although weightless—experience an alarming sensation of hanging upside down, because life on earth has conditioned him to associate celestial bodies with the regions above head level. This disturbing illusion has already been reported by pilots at high altitude, where stars may appear below the aircraft. It is of course to be expected that in practice the work in hand and radio-communication with his colleagues will keep the man's mind occupied for most of the time.

The confusion arising from misleading sensory stimulation will be worsened by anything which reduces visual acuity. The factors most likely to be significant in space are glare in sunlit regions and dark-vision when operating in planetary shadows. As indicated above, simultaneous contrast in space will be very strong and dazzling glare will tend to arise from any light-coloured or metallic surfaces. These effects reduce discrimination of fine detail and colour, while the ability of a man to see into space will be still further impaired by the veiling glare which can arise in transparencies and within the eye itself. The "windows" of space-vehicles will be subject to various types of misting, possibly including gradual etching by micro-meteorites. Bright light falling upon these surfaces will be scattered and help to reduce visibility. In addition to the action of solar ultra-violet radiation already mentioned, visible light striking the eye obliquely can itself produce veiling glare by scatter inside the eye—an effect which worsens with age.[6] It is fairly certain that in space any bright light scattered from optical surfaces or reaching the eye directly will effectively prevent the man from seeing anything at all in the inky void beyond. (For this reason, lunar explorers will not see many stars in the daytime.)

Hypothetically, the situation might arise in which a man in a space-capsule—while his satellite system was in a planetary shadow—would be required to locate some component by visual search. In the first place, he would be adapted to dark-vision, which implies a lessened ability to discriminate fine detail of form and shade. If the object is unlit, it will only be made out as a gap in the stars and it will be impossible to assess its attitude, distance or relative velocity (Appendix, Fig. 2). It will probably prove necessary to devise a system of lighting for orbiting vehicles and components, possibly incorporating a convention (Fig. 5) from which size, distance and direction of travel can be inferred visually as an adjunct to radio-location. The penalty for employing artificial lighting on and in space-vehicles will be the loss of dark-vision, which will mean that visual search for remote (and therefore dimly-lit) objects would be valueless. The radar-screen will probably be a more important feature of the space-vehicle's furniture than the porthole and, if to-day's television-addicted children are to be the builders of tomorrow's satellites, it may be that their education is more practical than we think.

Conclusion

A deliberately critical view has been taken in this discussion, if only to arouse a more detailed interest in the human problems of astronautics and to remind the enthusiasts on the engineering and logistic side that man is a probing and monitoring device of high sensitivity but specialized performance. They will have to make themselves fully conversant with his capabilities and weaknesses before incorporating him so casually into their schemes.

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GLOSSARY

Alveolar Air. The air in the finest subdivisions of the lung, where gases are exchanged with the blood.

Binocular Parallax. The effect whereby an object viewed against a more distant background is seen in slightly different positions by the right and left eye. The fusion by the brain of the two not quite identical pictures underlies our appreciation of depth, or "solidity".

Cornea. The transparent "window" at the front of the eye.

Dark-vision. Scotopic, or night-vision. In darkness, the sensitivity of the eye gradually increases many million-fold over its daylight level. This adaptation also involves a qualitative change, resulting in the effective loss of central vision. Increased sensitivity is bought at the price of detail and colour discrimination.

Negative g. Physiologically, *g* forces are defined as "positive" if they act from head to foot and "negative" if they act from foot to head. (A man hanging upside-down experiences 1 *g* negative.)

Neutral Density Filter. A filter which produces equivalent attenuation of illumination throughout the visible spectrum so that, although the brightness of the scene viewed is reduced, its colour values are unaltered.

P.s.i. Pounds per square inch.

Retina. The light-sensitive layer at the back of the eye.

Vestibular Organs. The organs of balance in the inner ear. They are the utricle and saccule, containing the otoliths, which respond to linear *g* and the semicircular canals, which are stimulated by angular accelerations of the head. A more detailed account of these organs is given in A. E. Slater's article "The Problem of Weightlessness", *Spaceflight*, **1** (3).

APPENDIX

Vision in Space

("In the country of the blind . . .")

Normal discrimination and depth-perception depend upon many different cues. Note the ring and the cylinder in the sketch (Fig. 1). Although they are very improbable objects, the observer can form a fair idea of their size, distance, attitude and even weight from perspective, their relationship to the men and other objects of known size, and a definitive vertical-horizontal frame of reference. (Also operating, but incapable of illustration, are binocular and motion parallax.)

Now suppose that the ring represents a hypothetical satellite in space and the cylinder some stray section. Is it large or small? Between us and the ring? What is its relative motion with respect to the ring and/or ourselves? Fig. 2 is a photographer's impression of an unlit satellite in a planetary shadow!

The only cue to its presence is a gap in the stars. Even if discerned at all, it is impossible to estimate its size, distance or velocity from its appearance alone. Approach or recession could be inferred from changes in apparent size.

(Fig. 3). Here the objects—of high albedo—are shown in full sunlight. Because of glare, the background of stars is largely lost to the eye. From its shadow, we can see that the cylinder is near the ring. But how far are they? How are they moving relative to the observer?

Fig. 4 shows the same system, almost "new" against a planetary segment. There are no cues from surface detail on the vehicle. Manifestly, the cylinder is nearer to us than the ring. How much nearer?

(Fig. 5). This is an impression of an illuminated system. The prominence of background stars will depend upon the brightness and colour of the lights. If all consecutive contour lights were a known, standard distance apart, the experienced observer could infer the attitude, size, distance and displacement of the two bodies.

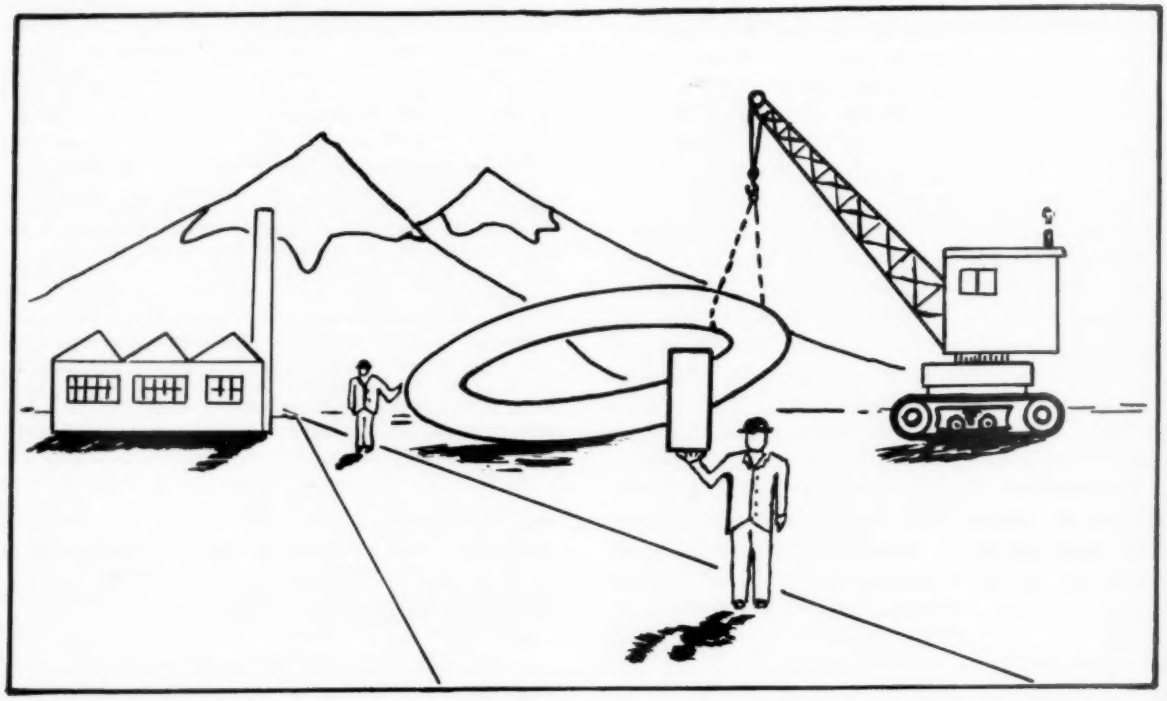

FIG. 1

FIG. 3

FIG. 5

FIG. 2

FIG. 4

Speculations on Extraterrestrial Life

By S. S. KIND

Can life exist on other planets? If so, what will it be like?

Most intelligent people have wondered at some time in their lives whether the Earth represents the only abode of life in the Universe. Various popular schools of thought have sprung up, usually based on little or no information and varying between ardently pro and unwaveringly anti. These schools of thought result from reasoning which may be religious, emotional or pseudo scientific, but is seldom scientific.

In truth the layman's view on the subject of whether or not there exists extraterrestrial life is almost as good as the scientist's for, after all, there are, roughly speaking, only two possibilities, there is or there is not!

The scientist, however, has a slight advantage over his lay friends in that he knows some things are not possible because of the existence of certain natural laws and he is thus prevented from making the more glaring mistakes.

Now that man is indeed on the threshold of space, discussions on extraterrestrial life will become more frequent. What follows is merely a short attempt to start the ball rolling in SPACEFLIGHT.

The Definition of "Life"

We must first begin by defining what we mean by "Life". There is at the present time no universally acceptable definition of "Life", and indeed there may never be. To some extent our definition will depend on what aspects of life we are interested in. In a restricted sense the definitions of both Al Read (Life is what you make it) and Professor Haldane (Life is any self perpetuating system of chemical reactions), are each acceptable.

For all we know there may be forms "Life" possible which are totally different in constitution from living things as we know them, but nothing useful would be gained in our present state of knowledge by entering into a welter of wild theorizing. For the present purpose we shall stick to life as we know it.

All living things, insofar as is known up to the present day, have as a basis the carbon atom. Their basic ground substance, *protoplasm* (Greek *protos*, first, and *plasma*, form) is made up ultimately of strings of carbon atoms in varying arrangements, straight chains, branched chains, and rings linked in some cases with other biologically important atoms such as nitrogen, oxygen, hydrogen, phosphorus, etc. Though these latter atoms are essential to life, it is the strings of carbon atoms which make up the basic structure of living organisms. This carbon can exist in various combinations with hydrogen and oxygen and with other elements, and in some of these combinations the carbon is in the reduced or energy-containing form. The most familiar example to us of a reduced carbon compound is ordinary cane- or beet-sugar. This substance contains carbon, hydrogen and oxygen in such a combination that it also contains a lot of energy. This energy is not a tangible thing; it weighs nothing and it is merely a consequence of the particular atomic constituents and their arrangement.

If we want to release the energy from the sugar, we can do one of two things. We can eat it or burn it. In either case the end result is the same, and we finish up with an oxidised or non-energy-containing form of carbon—carbon dioxide and some water. The flame and our bodies have done exactly the same thing, albeit a little faster in the case of the flame and a little slower in the case of our body. The overall reaction then is

Sugar + Oxygen (energy containing) → Carbon Dioxide + water (non-energy containing)

But where did the sugar come from in the first place? The answer lies not in the pot but in the form of the above equation written backwards, i.e.:

Carbon Dioxide + water → Sugar + Oxygen

and this reaction is carried on for us by green plants. The missing constituent from this second equation, energy, is supplied by the Sun's rays, and green plants are specially organized to trap this solar energy by virtue of their possessing a green pigment called chlorophyll.

So there are two contrasting processes in life, the *fixing* of energy and the *dissipating* of energy, carried out, roughly speaking, by plants and animals respectively. This must be true in any situation on any planet where life as we know it exists.

We will adopt for our definition of life then the following. Life is a carbon-based system which reproduces itself and is capable of using energy provided by chemical reactions in a water medium. The last clause is because all living things as we know them contain water and carry on their chemical reactions in a watery solution.

We are now in a position to consider the possible existence of life, as we know it, elsewhere in the solar system.

Possible Life-bearing Planets

The properties of water restrict the temperature range at which life can actively exist within fairly narrow limits. This range extends from a few degrees below zero (Centigrade Scale) up to a maximum of 60 or 70° C. At

S. S. KIND

the lower limit the water content of the living organism would be frozen solid and at the higher limit protoplasm begins to break down. Life in some forms can exist in a dormant state both below and above this temperature range, but for active growth at least part of the life span must be within the temperature limits defined above.

Most of the planets in the solar system can be immediately excluded on considerations of temperature alone, being either too hot or too cold, and the only two promising possibilities left are Venus and Mars.

Dealing first with Mars the astronomers have detected the presence of carbon dioxide in the Martian atmosphere and the presence of white polar caps which grow in the Martian winter and disappear in the Martian summer prove the presence of water. The temperature of the Martian surface has been estimated at an average of minus 28° C., which, of course, is very cold; but the evidence is that the temperature in the equatorial regions may on occasions rise as high as + 30° C., which is the temperature of a hot summer's day on the Earth.

The Martian atmosphere is thin, and although oxygen has not been detected, it may be there in small quantities.

Although the surface of Mars is incapable of supporting human life as we know it, there is some evidence from direct telescopic observation that the planet may support some type of vegetation. This is because of the appearance of green areas in advance of the melting polar ice cap in the Martian summer, which areas are, it is argued, green plants making the most of the water on the surface of Mars as it is released from the ice cap and before it is vapourized and redeposited on the opposite ice cap, where it is, of course, winter. Presumably in the intervening Spartan conditions these Martian plants lie dormant, a condition similar to that which various terrestrial plants can undergo.

It has further been argued, but less convincingly, that the particular type of green is similar to that of some terrestrial lichens which are capable of living under Arctic conditions, and this has been put forward as evidence for the existence of lichen-like plants on Mars.

Be this as it may, the existence of these colour changes is the most promising *direct* evidence of life on other planets.

Mars as an Abode for Man

It is probable that the surface of Mars will present a most unsuitable environment for man once he arrives there, as he inevitably will, assuming that he does not first blow himself to incandescent gas. Apart from the low temperature there will be other problems such as lack of oxygen and water (the latter, although present as noted above, is very scarce). The low atmospheric pressure would make it necessary at the very least to wear a breathing mask, and there is a high probability that a pressurized suit would be a necessity, since the minimum atmospheric pressure required to enable a pressurized suit to be dispensed with would be of the order of 4 in. of mercury. This is the pressure which exists at 45,000 ft. above the Earth's surface. For anything more than short-term existence the pressure would have to be a least an inch or two of mercury higher.

Since 4 in. of mercury seems to be about the maximum estimate of the atmospheric pressure on Mars, it looks as though we are condemned to our space-suits.

Venus

The second possibility as a life-bearing planet is Venus. This planet might superficially be thought to be a more promising abode of life than Mars, because it is approximately the same size as the Earth; is warmer than the Earth or Mars, and has a dense atmosphere. The most recent estimate of its day length puts it approximately equal to that of the Earth, which might be taken as another characteristic reminding us of home.

Our dream of this extra-terrestrial paradise has, however, been shattered by the astronomers who tell us that although carbon dioxide has been detected no water or oxygen can be found. This seems to destroy all hope of Venus as an abode of life, and conjures up a picture of the suffocating tropical hell of the Science Fiction writer. The situation, however, is probably not as hopeless as it first appears to be. Neglecting for the moment the probable absence of oxygen, it may be, the astronomers tell us, that there is water lower down in the dense Venusian atmosphere, where it is undetectable to present-day techniques. This is not merely wishful thinking, since most of the Earth's water vapour is confined to the

lower atmospheric levels and it is merely a case of extrapolation of knowledge gained from the Earth's atmosphere to Venus.

Should this in fact be the true state of affairs, then Venus may present today much the same picture as the Earth did hundreds of millions of years ago before the advent of the green plant gave us our oxygen by reducing carbon dioxide and water. It may not be a totally intractable problem to create sufficient oxygen on Venus for man to breathe freely by helping the process of atmosphere evolution along a little by seeding the planet with bacteria-size green plants some of which reproduce swiftly and are efficient oxygen producers. Since these bacteria in the absence of competition can grow exponentially (i.e. they not only increase but the rate at which they increase, increases!) then we may not have to wait astronomical lengths of time for the atmosphere to evolve to a breathable one. All this is, of course, no more than intriguing speculation, but it at least keeps the biologically minded of us occupied whilst the engineers get around to building a spaceship to take us to Venus and Mars to find out how right (or otherwise) we were.

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Air-breathing Boost Units for Long-Range Rocket Vehicles

By S. W. GREENWOOD

Some interesting proposals for turbojet-powered vertical-take-off-and-landing boost units for long-range rocket vehicles have been made recently by Mr. John B. Montgomery, general manager of the Aircraft Gas Turbine Division of the General Electric Company, of Cincinnati. The illustrations accompanying this note were supplied by the company, and show the scheme for a multi-engined boost unit which powers the vehicle during flight through the Earth's atmosphere, after which the multi-stage rocket takes over, the boost unit being recovered. Mr. Montgomery says that this feature of recoverability of the first stage makes the scheme more economical than those involving rockets alone. Another advantage claimed is increased mobility, in that the air-breathing first stages could be flown to the launching site, and the transportation and ground-handling facilities to support such a site would be simplified.

These proposals suggest that the development of turbojets of high thrust-weight ratio is anticipated by the company. If this aspect of performance can be steadily improved relative to the rocket engine then there appears to be a good case for combined systems of this type, where the advantage of the lower rate of vehicle-carried-propellant consumption of the air-breathing engine for a given thrust can be put to good effect during atmospheric flight.

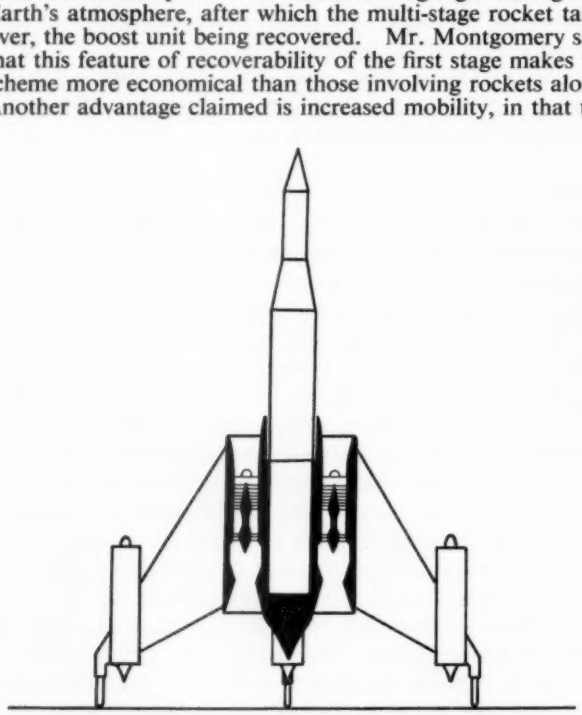


FIG. 1. Cutaway view of air-breathing boost unit demonstrates how turbojet engines could be nested together around intercontinental ballistic missile or space vehicle. Pods on boost unit also would contain air-breathing engines

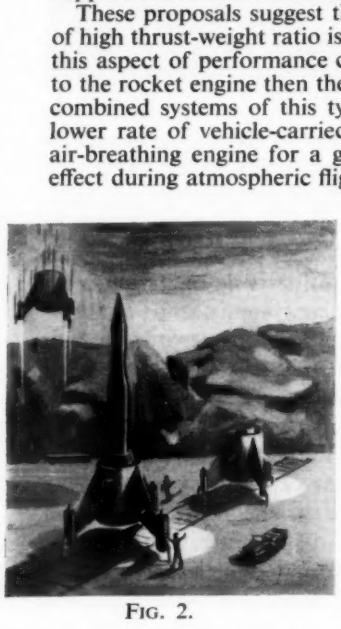


FIG. 2.

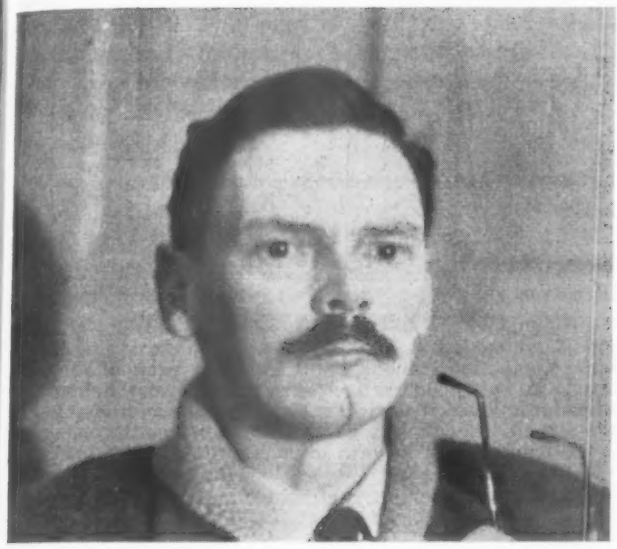
FIG. 3.

FIG. 2. This artist's drawing shows how air-breathing boost units, which could take off and land vertically, might be used to launch ballistic missiles. In the background, the drawing illustrates how a boost unit which already had launched a missile could be flown back to the small launching site for re-use. Transportation and ground-handling facilities to support such a launching site could be simpler than the elaborate structures being built for today's missiles

FIG. 3. Air-breathing boost unit could lift an intercontinental ballistic missile or space vehicle from a launching pad up through the heavy layers of air that lie close to the Earth. This drawing visualizes a boost unit containing 12 turbojet engines (three in pods and nine nested together in fuselage of boost unit)

Cosmic Radiation and its Possible Biological Effects

By T. F. SANDEMAN, M.B., CH.B.



DR. T. F. SANDEMAN

One of the main phenomena which will be studied with artificial satellites is that of cosmic radiation. On its elucidation will rest one of the factors to be taken into account when manned flight above the atmosphere is attempted.

Physical Background

To understand the nature and effects of these rays it is first necessary to know a little nuclear physics. The particles which concern us can be whittled down to three; the proton which carries a positive charge of electricity, the neutron which has practically the same mass as a proton, but carries no electrical charge, and the electron which has one two-thousandth of the proton's mass and carries a negative charge of electricity equal in magnitude to the charge of the proton. The atomic nucleus is made up of protons and neutrons and around it, in shells, whirl the electrons. In normal neutral atoms the latter are equal in number to the protons and also to the atomic number of the element. Hydrogen has a single proton for a nucleus and one electron in orbit. Helium has 2 protons and 2 neutrons in its nucleus and 2 electrons outside. Their atomic numbers are one and two respectively.

Radiation can be of two types, particulate and electromagnetic, the first apparently material, the second apparently a wave form. "Apparently" is inserted deliberately as in different circumstances particles behave like waves and vice versa. For instance, electrons can be diffracted like light and have a wavelength varying with the reciprocal of their velocity. When radiation acts upon matter it can affect the electrons or the nucleus, or the atoms can alter the quality of the radiation. Often a mixture of effects occurs and complete disruption of the whole system is not very rare.

Probably the most important interaction from the biological point of view is "ionization". This happens when radiation of any description knocks an electron out of its orbit and bounces off with reduced energy. The loss of an electron leaves the atom with an uncancelled positive charge and together with the free electron they make up an "ion pair". As the forces linking atoms together in molecules are contained in the outer layers of electrons, ionization may well lead to alteration of the molecular constituents. Only the less energetic radiations are completely absorbed in reacting with the electron and for the velocities which are associated with cosmic radiation at least two emissions are produced at each ionization—the rebounding electron, and the original ray minus the energy imparted to the electron. These are called secondaries, which may be highly energetic and proceed on their own account to produce further ions before they slow down sufficiently to be absorbed completely.

Uncharged radiation (E.M. or neutrons) can easily penetrate the orbits of the electrons to reach the nucleus. Positively charged particles tend to be slowed down by the nuclear field, but as the speed of a heavy charged particle increases so does the probability of it ending by striking the heart of an atom. If it traverses the electron fields to the nucleus it may be incorporated in the latter, transmuting it to a heavier element. Generally this atom is unstable and it ejects alpha, beta or gamma rays in an effort to reach stability. Alpha and beta particles are helium nuclei and electrons respectively. Gamma rays are short wavelength X-rays, i.e., they are electromagnetic radiations.

A really fast nuclear collison results in "star formation" which is just a splintering of the nucleus into smaller parts probably accompanied by some of the radioactive emissions. This effect is of biological interest as we shall see later. The nuclear "splinters" are also referred to as secondaries.

Lastly to confirm the interchangeability of energy and matter there are the phenomena of "bremsstrahlung" and pair production. The former is the emission of gamma radiation by an electron in slowing down without

striking anything, but as a result of passage so close to a nucleus that it undergoes great deceleration, and the latter is the conversion of high energy X- or gamma-rays into two particles each of the mass of an electron, one carrying negative charge—i.e., a normal beta ray—the other positive. This last is called a positron.

Excitation of an atom is of little interest in animal tissue as it is only the moving of an atomic electron into an orbit of higher energy. It is mentioned only for completeness.

It will be seen from the above that the interaction of radiation and atoms always results in the production of ionization sooner or later. Indeed, it is normally only the ionization produced that can be detected and the identification of the radiation and its energy is made from the distribution of the ions.

Known Constituents

There are a multitude of radiations careering around the universe, of which the most easily recognized is light. We must therefore define a lower limit to the energy of the radiation we intend to call cosmic. Having done so the pure primary beam must be differentiated from the secondaries it produces on meeting the outer layers of the atmosphere. At sea level the primary component is negligible so that to study it we must send balloons and/or rockets through the bulk of the atmosphere, carrying ionization detectors or photographic emulsions which will record the passage of a particle or ray through them.

As more and more of these flights are made our knowledge of the composition of the primary beam is revised. In 1952 the accepted approximate figures were: protons 80 per cent.; alpha particles, 19 per cent.; heavier nuclei, 1 per cent.; electrons and high energy X-rays, negligible. It will be noted that the most numerous constituents are hydrogen and helium nuclei. But the biological importance of the heavy component makes up for some of its rarity. Indeed, very recent work has shown that they are not as rare as these figures seem to indicate.

Secondary radiation is formed as soon as the primary beam meets the outermost atoms of the air blanket, many miles above the Earth's surface. There, however, the atoms are so few and far between that it is only when the rays get down to approximately 100,000 ft. that appreciable amounts of secondaries are formed. Deeper in the atmosphere these raise the intensity of radiation dosage above that of the primary beam. A consideration of the methods of ionization mentioned earlier will reveal how this is possible. Descending lower the denser air absorbs more and more of the rays as their energies fall off until only the most penetrating particles reach the surface. Fig. 1 shows that the highest intensity is encountered at 50,000 to 80,000 ft. As we are only dealing with the physical background it must not be presumed that the hazard to health is maximal at the same level.

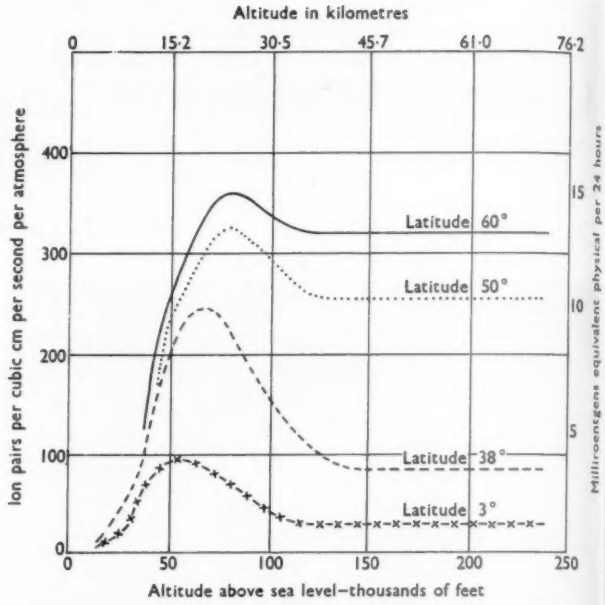


FIG. 1. Cosmic Ray Ionization Rate as a Function of Altitude for Several Geomagnetic Latitudes. The peak of ionization dosage at 50-80,000 ft. is due to the production of the secondary radiation most of which is eliminated in the denser layers of the atmosphere below this level. Above this region the atmosphere is too tenuous even to form secondary radiation by interaction with the primaries

(*J. A. Van Allen*)

Origin

Although nothing is known with certainty about the origin of these powerful radiations, adequate theories now exist to explain their enormous energies. It is now believed that the most energetic of the cosmic primaries are charged atoms which have been accelerated as a result of the movement of the magnetic fields which are associated with moving masses of interstellar gas clouds. Similar magnetic field variations in the outer layers of the Sun and other stars may also give rise to cosmic rays of lower energies. This is borne out by the fact that solar disturbances have an appreciable effect upon the cosmic rays reaching the Earth. This may also be attributed to the action of the solar disturbances on the magnetic field of the Earth and the external magnetic fluctuation of the Sun's field. It is strongly suspected that variations are due mainly to cosmic rays generated in the Sun.

Behaviour Near the Earth

We have already seen that the charged elements are sensitive to magnetic fields and as they approach us they enter that of the Earth. Even as far out as the Moon's orbit the magnetic flux may be sufficient to deflect the slower particles from their direct path. The force applied depends on the momentum and the amount of charge carried by the particle and the angle its path makes with the direction of the field. Maximum deflection is obtained with a slow moving particle carrying a large amount of charge travelling at right angles to the field. Therefore a particle has a better chance of

reaching the top of the atmosphere towards the magnetic pole than near the geo-magnetic equator. This means that the total intensity should be maximal towards the poles. In fact, by flying instruments to the top of the air blanket in balloons and rockets, or a combination of both, this theoretical gradation has been confirmed up to latitude 55° N. Nearer the magnetic pole the level of radiation does not rise to the postulated figure. This indicates that there is a low energy cut-off in the energy spectrum of the cosmic rays, i.e., no particles with less than a certain velocity reaches the Earth. One possible reason for this is that the Sun's magnetic field screens the Earth from low velocity cosmic particles.

Biological Background

Normal body cells consist of a nucleus (do not confuse this with the atomic nucleus) surrounded by protoplasm whose activities it controls. Each facet of a cell's functions and characteristics is governed by a pair of genes which are thought to be single complex molecules of unique structure, one for each facet. The genes are connected in chains, each of which contains between one and two thousand molecules. There are 23 pairs of chromosomes, as these chains are called, in each nucleus which means an approximate total of 70,000 genes in each cell. In body cells not all these genes have a specific function. Their importance is emphasised in the reproductive organs as the whole make-up of the next generation is determined by their structure. Everything from colour of hair, to intelligence, from approximate height to how early a man will go bald is contained, as if on a punched card, in the arrangement of the atoms of the genes.

When a cell divides each chromosome splits down the middle and each daughter cell receives its full quota of genetic material. However, there is no duplication of enzymes which are also large protein molecules. Enzymes have to be built up by each cell from food material using the gene as a template or mould. These molecules are used up in controlling the chemical reactions which go on in the protoplasm involving the billions of molecules of substrate. The substrate molecules form the main body of the cell.

The Effect of Radiation on Body Cells

For simplicity consider a single ionization occurring in a cell. This may lead to dissociation of a molecule. If the molecule which is disrupted is a functioning gene there will be no immediate effect as there will be a sufficient supply of the enzyme formed by the gene to continue the function which it controls for a period of up to weeks or months. Division of the affected cell will make the injury more obvious by halving the available supply of enzyme... In addition, in rapidly dividing tissues, the altered genetic material will be distributed over a large number of cells within a comparatively short space of time presuming that alteration of the gene does not render division impossible.

It is obviously more likely that a single ionization will occur in an enzyme or substrate molecule as they form the bulk of the cell but the loss of one molecule of either of these is unlikely to matter to the cell. To destroy appreciable quantities of the million or more molecules of enzymes in the cell many more ionizations must take place within the cell or, in other words, a heavier dose of radiation must be administered. The latent period before signs of malfunction appear would be reduced to a few days, and as quite a number of genes would be affected the cell would probably eventually die. To kill a cell outright a massive dose of radiation has to be given to destroy massive numbers of substrate molecules.

This is one theory which explains the main effects of "lightly ionizing" radiation such as X-, gamma- or beta-rays. Their high penetration means they distribute their ionizations sparsely along their tracks so that several single rays have to pass through the cell before even a light dose is absorbed.

However, for some biological effects the ionizations must be concentrated in time and space. For instance, a chromosome break requires 20 ionization events within a very small radius and almost simultaneous in time of occurrence. X- or similar rays will never achieve this without killing the cell at the same time, thus masking the effect of a chromosome break in the living organism.

Helium or heavier nuclei have very short ranges in tissue but produce large numbers of ion pairs in the immediate vicinity of their tracks, i.e., they have a high "specific ionization". These particles are eminently suitable for causing chromosome breaks which can then be studied. Conversely these densely packed ions are not so efficient in producing gene mutations, since they result in too many damaged genes in the one spot on the chromosome for their full mutative effects to be seen in the descendants. The ions are "wasted".

Note here that breakage of a chromosome may result in death of the cell when it divides as, either the chromosomes will not separate, or a portion may be left behind. The net effect is loss to the daughter cells of too great a quantity of genetic material to survive.

This, at least partly, explains the difference in severity of reaction to differing radiations in the same dosage and leads to the formation of the concept of Relative Biological Effect (R.B.E.).

X-rays are the usual standard when referring to a particle's R.B.E., so that if, for any particular biological reaction, a radiation's R.B.E. is 7, it is 7 times more efficient than X-rays in causing that effect. The effect is specified because a particle's R.B.E. may vary with the reaction studied. For example, the above figure represents the R.B.E. of 0·6 MeV protons (protons travelling with an energy of 600,000 electron volts) when causing blindness in mice. The same type of radiation has an R.B.E. of only 2 when its effect on the life span of the animal is measured. The reason for this variability is obvious in the light of the previous paragraphs and a consideration of the difference in penetration. High

energy X-rays will distribute their effects throughout the body while the greater ion density of the protons is concentrated in the superficial tissues of which the eye is one.

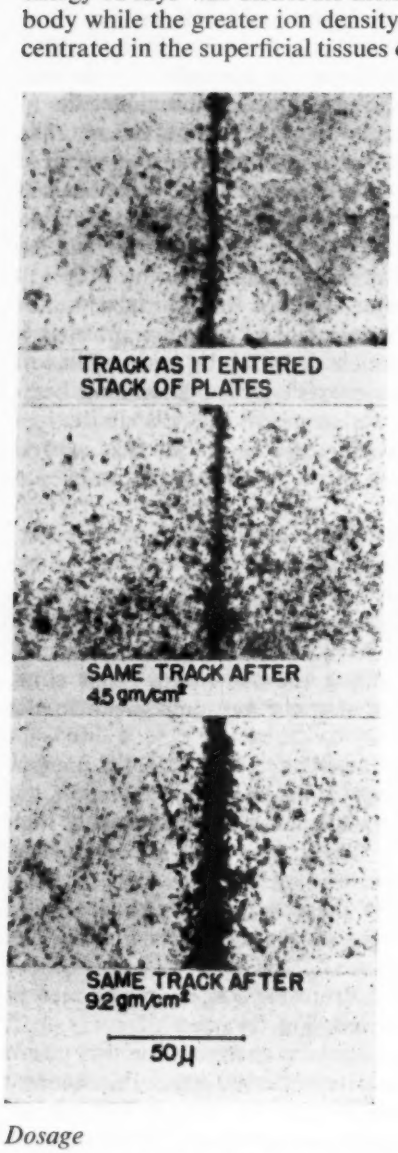


FIG. 2. A primary nucleus of atomic number 42 passing through a stack of photographic emulsions. The increase of ionization as the particle slows down is clearly evident
(*E. P. Ney*)

Dosage

In this situation the normal method of measuring radiation dosage, as used in X-ray and atomic energy work, is rendered inapplicable. The roentgen is the usual unit used and is a measure of the number of ions produced in air at standard temperature and pressure, and gives no indication of how these ions are distributed. In addition, the particulate portion of cosmic radiation behaves very differently in tissue from its behaviour in air.

A rough approximation can be obtained by multiplying the dosage in roentgens by the R.B.E. of the radiation concerned in the situation under examination. This quantity is known as the "roentgen equivalent man"—the r.e.m.

To complicate matters still further the R.B.E. of particulate radiation, especially the heavier nuclei, varies according to where in the track it is measured. As the particle is slowed to rest it becomes more efficient in causing ionization and it loses its energy more quickly in forming greater numbers of ion pairs. Once it is brought to a halt or is completely absorbed its ionization ceases. In other words, the Rate of Energy Loss (R.E.L.) and hence the R.B.E. rises sharply towards the end of a nucleus' track providing it terminates its journey by a gradual slowing to rest. With heavily charged particles the R.E.L. rises so high in the terminal few millimetres that figures for their R.B.E. at this point are just not available. These "thin-down hits" are, we believe, the most severe of any of the cosmic rays but luckily they form but a small percentage of the total, and as their penetration is low the damage they cause will be confined to the surface of the body.

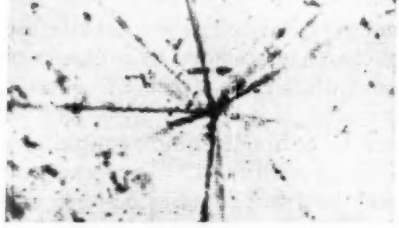


FIG. 3. A 14-pronged disintegration star in a nuclear emulsion. The prongs projecting in all directions from the centre are mostly out of focus. The magnification is almost twice that of Fig. 2
(*H. J. Schaefer*)

Their penetration depends on their initial energy, so that one might expect the injury to increase with increase in velocity. However, there is an upper limit to the speed at which a particle of particular mass will go through the thin-down phenomenon. As the energy increases so does the probability of the nucleus ending in nuclear disintegration as it strikes an atomic nucleus fair and square. This results in the splitting up of the primary into several portions of lower charge. Suppose a nucleus of charge 12 units splits into 3 portions, each bearing 2 units of charge and 6 of charge 1 unit. The ionizing power of a nucleus is proportional to the square of the charge so that the original particle had an ionizing power of 144. When it was shattered its ionizing capabilities dropped to 18 ($6 \times 1^2 + 3 \times 2^2$). In addition, nowhere is the ion density as high except at the centre of the star. Thereafter the rays spread throughout the tissue in all directions.

Material Studied

While we do not know the full effects of primary cosmic radiation on the human organism, and never will until prolonged flights are possible in free space, we have studied the biological reactions to other rays in man and animals. Short exposures of small animals to almost pure cosmic radiation have been achieved in balloon and rocket experiments.

The validity of any conclusions drawn from these sources must be doubted for the following reasons. Prolonged human exposure can only be studied as an occupational incidental as in radiographers. No great harm seems to have been produced in this class, but remember they only work with X-rays which have a low specific ionization and their exposure is intermittent. Animal experiments have the drawback that the variation

in response between species, even as closely related as rats and mice, is considerable. Exposures to primary cosmic radiation have been brief and it is possible that they have not included the absorption of the heaviest nuclei.

Extrapolation of Results

With these reservations in mind and assuming the worst possible radiation intensity we may expect the following signs and symptoms due to primary cosmic radiation.

First, thin-down hits by the heavy primaries are unlikely to affect tissues deeper than a few millimetres or centimetres beneath the skin. In the dermis itself they will probably cause tiny fine scars like those produced by repeated punctures by a needle. These may be painful. Scarring of the cornea and lens of the eye is a possibility and may interfere with vision. Hamsters flown at high altitude have developed white streaks in their hair as it grew following exposure.

Actual loss of hair is unlikely, as the total dose is not high enough, but the more penetrating rays over a long period may well produce a mild anæmia. As the load on the heart will be lightened in zero or sub-gravity conditions it is probable that this will be well compensated until return to Earth.

In some subjects prolonged low dosage irradiation may cause cancerous changes particularly in the skin. One can be even less definite on this point than the others but if it is any consolation, cancer in this site is easily treated and should be quickly recognized if one is on the look out for it. Recent work has indicated that cancer of the blood-forming organs—leukæmia—can follow even low doses of penetrating radiation.

Irradiation of food, air and water does produce radioactive poisons but their concentration will be far below the safety limit laid down for workers in atomic plants.

Gene Damage

So far we have dealt with damage to the somatic or body cells and hence to the individual only. More important probably are the effects on the reproductive or sex cells, and they deserve a section to themselves.

Returning for a moment to biological principles we find that when the male and female sex cells (the sperm and the ovum) mature they go through a "reduction division" in which the cell divides without duplicating its chromosomes. Each half receives one member of each pair of chromosomes, a total of 23, so that when union of sperm and ovum takes place the number is again returned to the normal 46. This united cell is the next generation and on repeated division and differentiation it forms a complete individual who inherits half his genes from each parent. The chromosomes are not passed complete from grandfather to grandson. Some interchange between members of the same pair occurs at the first meeting between sperm and ovum so that a mixture of inheritable characters ensues, although a prominent feature, e.g. the Hapsburg nose, may be identifiable for many generations.

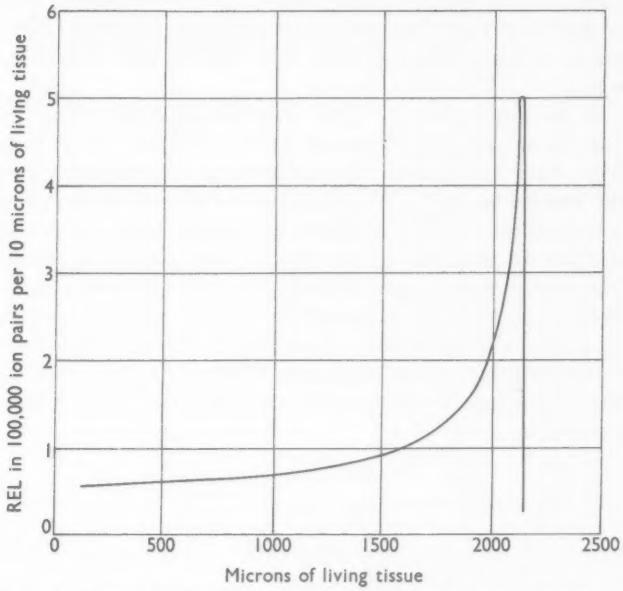


FIG. 4. Bragg Curve of a Heavy Nucleus of Atomic Number 12 and 800 Million Electron Volts Kinetic Energy in Living Tissue. The particle comes to rest approximately 2.15 mm after penetrating the surface. In the terminal 0.6 mm of its journey it produces over 100,000 ion pairs every 10 microns (1 micron= 1/1,000 mm)

(*H. J. Schaefer*)

Such a feature is a "dominant" and will take precedence over a "recessive" in producing the effect considered. The degree of dominance is determined in the gene which carries the character and the frequency of its appearance may vary in the first few generations. As an example take a pure-bred (i.e. both chromosomes contain identical genes for the character) blue-eyed man and mate him with a pure-bred brown-eyed woman. Suppose the gene for blue eyes is completely dominant over that for brown eyes and that the family ensuing from this mating is restricted in having to choose mates from their brothers or sisters. Assume also that each mating results in 4 children. In the first generation of children all will have blue eyes but all will carry the recessive brown-eyed mutation. If they produce 8 children 2 will be pure blue, 2 pure brown and 4 will resemble their parents in being hybrids. If the pure blues do not marry each other but mate with any of the others and the same applies to the pure brown the next generation will contain 25 per cent. pure blue, 60 per cent. hybrid and 15 per cent. pure brown. Note now that, while over 4/5th of the stock are blue eyed there are twice as many with the recessive gene as pure bred.

Radiation damage to the gene results in mutation if only a single or very few ionizations occur. Mutations are almost always deleterious and recessive if they are capable of being inherited. The only types of radiation which can reach the sex organs, since they are reasonably protected, are the penetrating ones which are lightly

ionizing and hence most efficient in producing mutation in a single gene. As only one ionization is sufficient there is no safety factor apart from statistical improbability that the ionization will occur in the right place. Continued exposure will reduce this improbability.

It becomes obvious that radiation-induced recessive mutations are cumulative not only in the individual but, since they are passed from generation to generation, in the species as well. While only a few people are exposed to radiation the vast numbers of healthy individuals are capable of absorbing and diluting the abnormal genes like a beaker of water dissolving a small quantity of salt. When more and more people receive increasing amounts of genetically dangerous radiation the concentration of mutations must rise and a crystallization point will be reached when the abnormal birth rate will suddenly leap upwards.

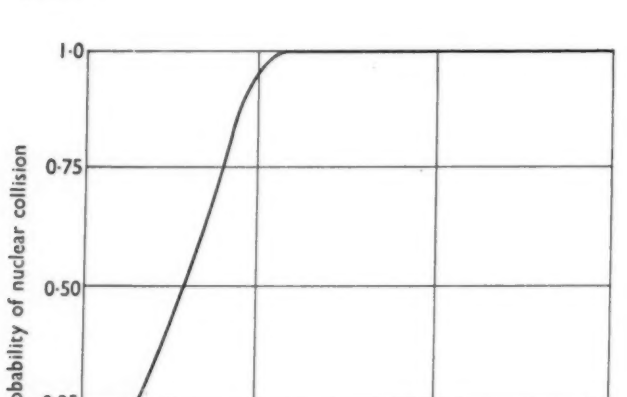


FIG. 5. Probability for a heavy nucleus of the Carbon, Nitrogen, Oxygen group undergoing a nuclear collision with the production of a nuclear star. Note that as the energy rises above 1 BeV the nucleus is almost certain to end in a nuclear burst instead of undergoing the thin-down phenomenon

(*H. J. Schaefer*)

At the moment and in the near future only a few males will be exposed to any concentration of cosmic radiation and that for short periods while flying. Flights at 70,000 ft. are still rare enough to add little to the genetic hazard. So long as one partner only is involved the first generation will not be affected noticeably. Intermarriage within this group will tend to uncover the genetic damage by increasing the probability that two recessive genes will meet in the ensuing generation.

Looking far into the future, when colonization of the planets may be a technical possibility, if the hazard has not been reduced it is very unlikely that any settlement will survive beyond the second or third generation if the colony is small. Both males and females would be exposed for a considerable length of time in transit.

Protection

With present-day techniques the outlook is just as depressing when we consider methods of shielding.

On the Earth's surface the thickness of the atmosphere affords physical protection against all the grossly damaging cosmic rays. Once we leave this, if we require a shield we must take it with us. Unfortunately, a reasonable thickness of aluminium, say 1 to 6 cm., actually increases the health hazard by forming secondary radiation and slowing the faster heavy particles to a speed where they are more likely to form thin-down hits than nuclear stars. To be effective the metal would have to be 3 in. thick or if steel were used, 1 in. thickness would be required.

For the other components the lighter the material of the shield the more effective it is, and possibly the only practical way of achieving adequate protection without uneconomic weight penalties is to site the life compartment in the middle of the fuel tank—assuming the use of a chemical fuel.

The deflection of the damaging rays by a magnetic field might be utilized by placing a powerful magnet along the axis of a cylinder round which the crew cabin is built.

Physiological protection is possible against the lethal effects of laboratory radiation. For instance, hormones, alcohol, and the injection of normal bone marrow will reduce the number of deaths from lethal doses of X-rays. Lowering the cell's metabolism by depriving it of oxygen and warmth will do the same thing; but even supposing this phenomenon is applicable to cosmic rays, how can a crew be kept working at optimum efficiency using any or all of these devices?

Conclusion

While the immediate risk to the life of an occupant of a space vehicle from cosmic radiation is not measurably higher than that he runs from meteoric collision, the long term effects are prohibitive for anyone who hopes to have children after any great exposure. Weight considerations make physical protection difficult.

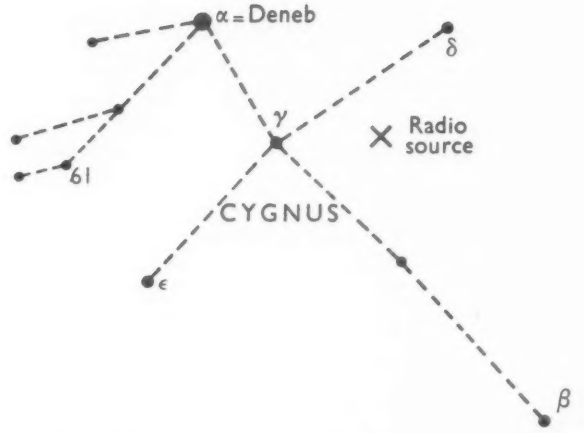
The remarks on genetic effects are equally and probably more immediately applicable to the total dose of radiation received by the population from background radiation, luminous instruments, diagnostic X-rays, and atomic explosions and their fall-out.

Figs. 1, 2, *and* 4 *reproduced by kind permission of the authors from "Physics and Medicine of the Upper Atmosphere," edited by Clayton S. White and Otis O. Benson, Jr. (University of New Mexico Press, Albuquerque,* 1952). *Figs.* 5 *and* 6 *reproduced by kind permission of H. J. Schaefer from U.S. Naval School of Aviation Medicine report NM OOL,* 05913,05 *and The Journal of Aviation Medicine,* 1954, **25**, 338.

Sky Diary: July to September, 1958

By A. E. SLATER

A year ago, in "Sky Diary", much was said about the constellation Cygnus, the Swan, which is just south of the overhead point at about midnight in mid-July, at 10 p.m. in mid-August and 8 p.m. in mid-September (local time). But there is still more to be said, especially from the point of view of the would-be interstellar traveller, who has two quite different reasons for being interested in one particular star. This is 61 Cygni, a faint star of the fifth magnitude which does not form part of the "cross" of brighter stars by which the constellation is recognized. Its position in relation to the bright star, Deneb, at the head of the cross is shown in the diagram (a larger chart, including neighbouring areas, was given in *Spaceflight* for July, 1957, p. 151).



In the first place, 61 Cygni was the first star to have its distance measured—at least, by somebody on Earth. He was Friedrich Bessel, and in 1838 he made its distance to be about 10 light years; the distance is now known to be about $10\frac{3}{4}$ light years, or more than twice that of the nearest star known. A small telescope shows it to be a double star, the two components being separated by 24 sec. of arc, which means that their actual distance apart is rather more than the maximum (aphelion) distance of Pluto from the Sun. One of them, seen from the other, would scarcely look big enough for its disc to be distinguishable. 61 Cygni appears to be moving at 30 miles a sec., so 400,000 years ago, when Pithecanthropus walked the Earth, it must have been seven times as far away as it is now.

The other point about 61 Cygni is that it is the first star, other than the Sun, which was discovered to possess a planet. It is no use looking for this planet with a telescope; its presence was inferred by K. A. Strand only because it perturbed the motion of one of the component stars, round which it evidently revolves. Strand calculates its mass to be 16 times that of Jupiter, so we can presume its atmosphere to contain probably a lot of hydrogen and no oxygen. As Dr. Strughold pointed out in his paper read at the Rome I.A.F. Congress, a planet must be not only at the right distance from its Sun, but also of the right size, if it is to bear life. But I seem to remember, many years ago, Sir James Jeans proving to his own satisfaction that no planet could possibly be bigger than Jupiter!

Also marked on the diagram is the position of the well-known radio source in Cygnus—the second most intense source yet discovered, believed to be due to the collision of two spiral galaxies face-on. Some readers might be interested to look at the exact spot, though we could not expect to see anything there unless Nature had given us eyes as big as radio telescopes (and even the most glamorous film star cannot boast "saucer eyes" of that calibre). Perhaps, somewhere in our galaxy, there are beings who have evolved such eyes; to them, this radio source would probably appear the second brightest object in the night sky. The colliding galaxies have been photographed, but they are only of the 18th magnitude in brightness.

This quarter of the year includes the most conspicuous of all the regular meteor showers—that of the Perseids, which are at their best from August 10 to 13. For a single observer the hourly rate averages 60, but it is less than this in the early evening, when Perseus, from which the meteors appear to radiate, is low in the sky to the NNE., and improves during the night because (1) the radiant point rises higher, and (2) we get carried round towards that side of the Earth which faces its direction of motion—until, some time after midnight, the Moon comes up and spoils visibility by lighting up the sky background. A good imitation of a meteor shower, though very much speeded up, can be got by driving an open car through a snowstorm at night with the headlights on; the bright snowflakes all appear to diverge from one point. But this point shifts if you change the speed or direction of the car, showing (*a*) that the radiating motion is an optical illusion because the paths of the snowflakes, like those of the meteors, are really parallel, and (*b*) that the Earth's motion partly determines where the radiant point is.

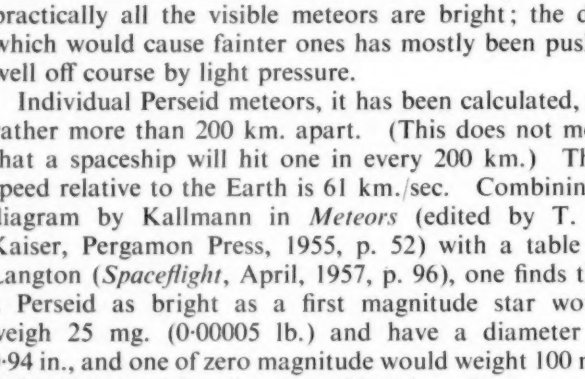
The meteors do not, of course, necessarily come into view in Perseus; they may appear in any part of the sky, according to where they enter the atmosphere; they are stated to burst into view at heights between 112 and 93 km. and to fade out between 88 and 78 km. It is an interesting exercise to prepare a chart of the part of the sky you intend to look at, including Perseus if possible,

and then mark in the paths of all the meteors you see. Then produce these paths backwards; most of them will converge on to Perseus, and the others, if any, cannot belong to the Perseid shower.

The orbit of the Perseids is inclined at 65° to the ecliptic, so they do not get disturbed by other planets; further, their motion is retrograde. Both these features lead to the orbit being stable; in fact, Perseids have been reported in August for over 1,200 years, although it was not till 1862 that a comet was found following the same orbit, as often happens with meteor showers. This comet has a period of 120 years, so many readers may see it again, though the shower is so old that there is unlikely to be much concentration of meteors near the comet. Another effect of the shower's age is that practically all the visible meteors are bright; the dust which would cause fainter ones has mostly been pushed well off course by light pressure.

Individual Perseid meteors, it has been calculated, are rather more than 200 km. apart. (This does not mean that a spaceship will hit one in every 200 km.) Their speed relative to the Earth is 61 km./sec. Combining a diagram by Kallmann in *Meteors* (edited by T. R. Kaiser, Pergamon Press, 1955, p. 52) with a table by Langton (*Spaceflight*, April, 1957, p. 96), one finds that a Perseid as bright as a first magnitude star would weigh 25 mg. (0·00005 lb.) and have a diameter of 0·94 in., and one of zero magnitude would weight 100 mg. (0·00022 lb.), with a diameter of 0·15 in. From a graph by Langton (*J.B.I.S.*, Sept., 1954, p. 292), a Perseid of zero magnitude on the stellar scale should just be stopped by a "meteor bumper" of chrome steel 1 mm. thick. Think of this as you watch the meteors and estimate their brightness.

Venus rises two hours before the Sun in July and August, but draws in towards it during September, when, however, it can be used to locate Mercury, which passes 2° south of it on September 5, at 2 a.m., and only 0·3° north of it on the 18th, though this happens at 6 p.m. G.M.T. Between these dates it is to the right of Venus. Jupiter and Saturn are already up by sunset.



"Ah, but what's the position if the world doesn't last 10 years?"

From a cartoon by Friell of the London Evening Standard

Mars is getting nearer and will be rising before midnight by the end of July. By the end of September it is 16 sec. of arc in apparent diameter, compared with 19·2 when at its nearest on November 9. Any particular feature on its surface comes round about 40 min. later each night; the most conspicuous one, Syrtis Major, crosses the central line of the Martian disc at midnight on July 10, 11 p.m. on August 15, and 9 p.m. on September 18—so you can interpolate from these figures. The Moon will pass in front of Mars on August 7 as seen from North America and on September 4 as seen from Australasia and S.E. Asia.

The Explorers

Beside the Mare Crisium, that sea
Where water never was, sit down with me
And let us talk of Earth, where long ago
We drank the air and saw the rivers flow
Like comets through the green estates of man,
And fruit the colour of Aldebaran
Weighted the curving boughs. The route of stars
Was our diversion, and the fate of Mars
Our grave concern; we stared throughout the night
On these uncolonized demesnes of light.
We read of stars escaping Newton's chain
Till only autographs of fire remain.
We aimed our mortal searchlights into space
As if in hopes to find a mortal face.

O little Earth, our village, where the day
Seemed all too brief, and starlight would not stay,
We were provincials on the grand express
That whirled us into dark and loneliness.
We thought to bring you wonder with a tale
Huger than those that turned our fathers pale.
Here in this lunar night, we watch alone
Longer than ever men have watched for dawn.
Beyond this meteor-bitten plain we see
More starry systems that you dream to be,
And while their clockwork blazes overhead
We speak the names we learned as we were bred;
We tell of places seen each day from birth—
Obscure and local, patois of the Earth!
O race of farmers, plowing year by year
The same few fields, I sometimes seem to hear
The far-off echo of a cattle bell
Against the cratered cliff of Arzachel,
And weep to think no sound can ever come
Across that outer desert from my home!

ADRIENNE CECILE RICH

Reviews

From the Aratus Globe to the Zeiss Planetarium. By Helmut Werner (translated from the German by A. H. Degenhardtt). Verlag Gustav Fischer, Stuttgart, 1957.

This book is a description of the Zeiss Planetarium, together with a history of the idea of portraying celestial phenomena artificially, and a detailed study of the design and construction of the modern form of the instrument as manufactured by Zeiss. The book is to some extent an advertisement for the firm of Zeiss, but this is fair enough, as Zeiss are the only firm who make these instruments in quantity, and the entire development and construction, together with the initial research, is an achievement for which they have a right to feel proud. The original idea was proposed in 1913, and the invention of the modern form of the instrument is due to the work of Professor Bauersfeld, Director of Carl Zeiss. His photograph is the first in the book, and it must be very gratifying to have designed such a successful and complicated piece of scientific equipment which has a purely educational use and is not likely to be perverted into an instrument of destruction by the military or political mentality. The book has a very luxurious appearance, is printed on good paper, and contains a large number of fine photographs and diagrams. There is even a 3-D photograph of a planetarium at the end of the book, together with viewing spectacles in a holder attached to the inside back cover. It is a pleasure to be able to say that the text comes up to the high standard of production and printing.

The first 28 pages are concerned with the history of the planetarium. The first mention of a device for reproducing the motion of the stars dates back to the times of the Pharoah Akhenaton in the fourteenth century B.C. It must be remembered that all the ancient planetaria did actually depict the motions of the stars, because until the sixteenth century it was thought that the stars rotated around a central stationary Earth. Most of the early devices were globes with the constellations either painted on the surface or shown in relief. The *Farnese Atlas* is a good example of the latter, and a photograph of this is shown on p. 15. To obtain an idea of the motion of the constellations, it was necessary either to rotate the globe, or for the observer to walk round it. One of the best of the early globes must have been that of Ptolemy, which is no longer in existence, but was described by him in his large handbook on astronomy about A.D. 150. What may have been an even more elaborate device was made by Archimedes about 250 B.C., although there are no details of this extant. It was, however, captured by the Romans and seen by Cicero about A.D. 100. Archimedes' device demonstrated the motions of the planets, the Sun and the Moon, and could also represent eclipses. The apparatus was probably housed in a hollow metal or glass globe and worked by water power. The remains of a similar planetarium were found in the wreck of an old ship sunk off the coast of Greece, and consist of a number of accurately made bronze gear wheels whose exact function is unknown, but there is no doubt that these ancient devices were more than simple celestial globes. In the dining room of Nero there was a machine which "moved through day and night like the universe".

It was not until the seventeenth century, however, that the modern planetarium was foreshadowed by such devices as the "Gottorp celestial globe", described on p. 20 of the book. This was a large copper sphere about 4 metres diameter, inside of which a few spectators could sit. The stars and constellations were painted on the inner surface. Similar devices, with external illumination and small holes in the surface of the globe, have also been constructed. The last, and most impressive of the mechanical planetaria described in the book is the Copernican planetarium at Munich. Here electric light bulbs running on rails in the ceiling of a cylindrical room simulate the motion of the solar system. All these devices, however, fail to produce an illusion of the heavens which is acceptable as such to the observer. They are also clumsy and inflexible in operation, and it was not until 1919 that Bauersfeld conceived the idea of reversing the accepted principle of a rotatable sphere, and instead developed the system of a fixed sphere with a moveable projection system at the centre.

Chapters 2, 3 and 4 describe in detail the design and development of the modern form of Zeiss Planetarium. The prototype model took five years to design and build, and the first commercial model was installed in Munich in 1925. After extensive tests of the first two models, an improved version was evolved, and this second type is the one which has been made ever since, and is the type which has recently been installed in Madame Tussauds in London. An extremely detailed account of the planetarium mechanisms is given in these three chapters, together with many photographs and diagrams explaining the gear systems, projection devices and methods of adjustment and control.

Chapter 5 deals with the supplementary instruments which can be added to the equipment to increase the range of astronomical phenomena which can be displayed. For example, a comet projector can be attached to the star projector, and a photograph in the book shows the great Donati Comet as it was seen in 1858, projected in a planetarium against the artificial star background. A small auxiliary projector standing on the lecturer's table can be used to simulate shooting stars, whilst the Zodiacal lights can be produced in the correct colours by a similar device. A projector is available for superimposing the constellation outlines, according to mythology, on to the star background. Photographs of these devices, and of many others, and of the effects they produce, are given in this chapter.

The next chapter deals with the methods of presenting a planetarium demonstration, and gives some examples of the various lecture programmes and demonstrations that can be arranged, including the improbable sounding one of Dante's journey through the interior of the Earth during his conducted tour of the lower regions, culminating with his emergence in the Southern Hemisphere. During the three minutes taken to describe Dante's downwards journey, the planetarium projector is switched off, and the operator readjusts the controls to give the Southern night sky. It says in the book, "This sudden appearance of the strange new heavens makes a powerful impression".

In this chapter there are also suggestions for background music, and even some examples of appropriate poetry which can be quoted with "becoming effect".

The final chapter of the book considers briefly what conclusions would be drawn by a scientist in a few thousand years time, if the only evidence of our present civilization that had survived was a planetarium. We would, apparently come out quite well in the limited field of astronomy, if not in that of survival techniques.

The last portion of the book consists of three appendices, a bibliography, a glossary of astronomical terms, an index, a table of corrections and amendments, and finally, a table of contents.

Appendix I contains photographs and brief descriptions of planetarium buildings in various parts of the world, with particular reference to the construction of the domes. Appendix II consists mainly of 39 photographs illustrating the siting of planetaria in various cities, including a photograph of the one in Rome, which is erected in the hall of the ruins of the thermal baths built for the Emperor Diocletian (A.D. 300), no doubt giving one the unique opportunity of observing Andromeda in a bath. A list of existing planetaria mentions 38, excluding the London one. Appendix III is about the latest developments in the instruments, and mentions some which have been constructed by other organizations, mainly to the same design as the Zeiss instrument, but generally of more limited operational scope. The London planetarium is described very briefly at the end of this Appendix.

The Bibliography which follows lists 241 references to books and papers on the subject, and, in the Glossary, 92 astronomical terms are defined. There is a good Index, and, finally, the 3-D photograph of the Hamburg instrument already referred to previously.

This book can be strongly recommended to those who require a very complete and highly authoritative account of a modern planetarium and its operation. The descriptive and historical chapters are easy to read, whilst those which deal with the technical details of the construction and operation of the instrument are more difficult, not because they are poorly written, but because they are describing a very complex piece of precision optical engineering, the detailed operation of which is not easy to understand. N. H.

Soviet Sputniks, "Soviet News" Booklet, No. 25, London, 1958. 52 pp. Price 1s. 3d.

This booklet, well illustrated with photographs and diagrams, is based on material published by Soviet scientists, and gives a popular account of the Russian achievement in successfully launching the world's first Earth satellites—Sputniks I and II—and outlines some of the implications of this epoch-making event.

Among other things, it seems clear that Soviet plans for the despatch of an instrument-carrying rocket to the Moon are well advanced (such a flight is described as "a matter of the near future") and that the exploration of the planets is also envisaged. A proposed Martian project, calling for the extra-terrestrial assembly of ten spaceships, each weighing 1,700 tons, is regarded as a possibility by the end of the present century. P. E. CLEATOR.

He Lit the Lamp: a biography of Professor A. M. Low. By Ursula Bloom. Burke Publishing Co., 1958. 214 pp. 18s.

Few can doubt that A. M. Low was a most interesting man. He possessed a brilliant brain; it has often been maintained that he never used his talents to the best advantage, but even so he accomplished much. He was also a "popularizer" of science, and, like all successful popularizers, had to endure ill-natured criticism from those who considered themselves better qualified, but who had no real idea of how to write science for the layman.

In this book Miss Ursula Bloom gives an account of Low's life and achievements. She does not gloss over his weaknesses, and there are also some good photographs.

It cannot honestly be said that the book is a success. It is too scrappy, and has been compiled with insufficient care; for instance, the periodical *Spaceflight* is referred to as *Starlight(!)* and it is said, quite wrongly, that Low resigned the Presidency of the B.I.S. in 1951. The reviewer has noticed a good many other mistakes. However, it does at least underline the need for a really good biography of Low; it is to be hoped that such a book will be written before long. K. E. S.

Our Moon. By H. P. Wilkins. Frederick Muller, London, 1958. 180 pp. 15s.

The first edition of Wilkins' *Our Moon* appeared in 1954, and quickly became known as one of the best introductions to lunar study. Its reappearance in the second edition is therefore most welcome. The author has made a few minor modifications which serve to bring the book up to date, but there are no important differences.

The first chapter, "Prehistoric Times to Galileo", contains an account of the history of selenography. "The Motions of the Moon" are then dealt with, clearly and non-mathematically, after which there follow six chapters dealing with the appearance of the Moon through the telescope; the author takes us for "a week's observing", and describes the changing appearance of the Moon from night to night as it passes from new to full. The remaining chapters deal with such matters as "A Day on the Moon", "The Other Side of the Moon", and "Mysterious Happenings on the Moon". The text ends with a discussion of "Our New Colony". Wilkins takes a realistic view of the interplanetary problem, and he is clearly of the opinion that the Moon will be reached in the reasonably near future.

The appendices include a map of the surface, with a brief account of each important feature; some useful tables; and a bibliography. The photographs are well chosen, and the line drawings satisfactory apart from the sketch on page 60, which should be improved for the next edition.

Altogether this is an excellent book; clear, readable, informative and of value to all those who take any interest in astronomy or astronautics. It can be recommended heartily.

Perhaps the final paragraph of the book is particularly worth quoting in a review. Wilkins says: "This is the story of the Moon, as she was in the past, is today, and what she will become in the future. From being an object of worship she has become a world of absorbing interest, with her widespread craters and lofty mountains. If at present a dead world, she is destined in the not far distant future to lodge the 'lords of creation'. May this irruption be peaceful for this magnificent orb."

J. A.

"He wants to file a complaint about our last guided missile test."

Courtesy of U.S. Navy—Bureau of Personnel Information Bulletin—April, 1957